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Contribution to the knowledge of Mediterranean wetland vegetation: *Lemnetea* and *Potamogetonetea* classes in Western Sicily

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Abstract

The freshwater aquatic vegetation of the *Lemnetea* and *Potamogetonetea* classes in Western Sicily was surveyed and analyzed. 85 lakes and small pools were investigated collecting 147 phytosociological unpublished relevés to integrate the very scarce available data (only 3 relevés). By applying statistical analyses on abundances data and on the bases of physiognomy and dominant species, two alliances (*Lemnion minoris* and *Stratiotion*) and four different coenoses have been identify for the *Lemnetea* class; while 11 associations, assigned to two orders (*Potamogetonetalia pectinati* and *Callitricho hamulatae-Ranunculetalia aquatilis*) and four alliances (*Potamogetonion*, *Nymphaeion albae*, *Ranunculion aquatilis* and *Ranunculion omiophyllo-hederacei*) have been recognized for the *Potamogetonetea* class. A new association (*Junco bufonii-Ranunculetum omiophylli* ass. nov.) and a new subassociation (*Ranunculetum peltati ranunculetosum rionii* subass. nov.) have been proposed, whereas other six vegetation units were found to be new for the study area (*Potamogetono-Ceratophylletum submersi*, *Potamogetonetum pusilli*, *Ranunculetum aquatilis*, *Ranunculetum peltati* and *Ranunculetum rionii*, *Lemno-Callitrichetum obtusangulae*). For all the coenoses recognized, new insights on the floristic composition, syntaxonomy, synphiognomy, synecology and synchorology are reported, offering a reasoned overview of the aquatic vegetation of the western sector of the main Mediterranean island.

Keywords

aquatic vegetation, biological conservation, Mediterranean islands, phytosociology, plant community classification, Sicily, small standing-water ecosystem

Introduction

Inland small standing-water ecosystem act as preminent hotspots for biodiversity although they are globally threatened (Bolpagni et al. 2019). Reclamation, eutrophication, fragmentation, and alien species invasion along with the effects of climate change are just some of key threats affecting freshwaters and wetlands (Benavent-González et al. 2014; Angiolini et al. 2017; Reid et al. 2019). Indeed, freshwater biota, and macrophytes in particular, are counted among the biological components that are most at risk of extinction under Anthropocene conditions (Bolpagni et al. 2018; Dudgeon 2019). This is especially true for the Mediterranean islands which are the backbone of one of the most diverse biodiversity-rich areas worldwide (Cañadas et al. 2014).

To this respect, Sicily – the largest Mediterranean island – is a key case study due to the intrinsic rarity of humid habitats and macrophytes (Troìa & Lansdown 2016; Minissale et al. 2017; Romanov et al. 2019). Inland small standing-water ecosystem are normally found in small depressions from the low hills to the mountainous areas

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(Caldarella 2014), interspersed within different land use types (e.g., agricultural areas, pastures, prairies, garrigue, forest clearings, wooded environments). Furthermore, they are under the control of a multiplicity of local environmental (e.g., exposure, altitude, shading, surrounding vegetation, hydroperiod, water supply) and anthropogenic drivers (e.g., trampling, water withdrawals, reshaping of banks).

This kind of habitats has always generated interest from botanists. Indeed, in Sicily the wetland flora investigation dates back to the dawn of floristic research (Gussone 1827-1828, 1842-1845; Lojacono-Pojero 1888-1909; Giardina et al. 2007). Despite this, the knowledge of wet vegetation, particularly the strictly acquatic one, remains scarce and fragmented, often limited to few contributions referring to single biotopes. Some examples of this are the "Gorghi Tondi" and the Preola Lake in the Trapani area (near Mazzara del Vallo; Suppl. material 2, Figure S2f) (Brullo and Ronsisvalle 1975), the wetlands of the "Bosco del Cappelliere" in the surroundings of Palermo (Gianguzzi and La Mantia 2004; Caldarella et al. 2013b; Caldarella 2014; Caldarella and Gianguzzi 2018), the lakes of Serradifalco and "Bosco" in the Caltanissetta area (Marcenò and Raimondo 1977), the "Gorghi" of Carcaci and Carcaciotto (Suppl. material 2, Figure S3a) on the Sicani Mountains (Gianguzzi et al. 2007), and the "Gorgo di Monte Cofano" (Gianguzzi and La Mantia 2009; Suppl. material 2, Figure S1e).

To fill this knowledge gap, the present work concerns the phytosociological survey on the aquatic coenoses of the *Lemnetea* and *Potamogetonetea* classes, carried out through numerous unpublished relevés, in addition to the scarce available data (only 3 relevés). The survey involved the most representative biotopes of the Western Sicily (85 different lakes and small freshwater ponds and pools), distributed from the coastal area to the mountain belt, spread over various geological formations and with different hydroperiods.

Materials and methods

Study area

The study area comprises the western sector of Sicily, including the provinces of Trapani, Palermo, Agrigento, and Caltanissetta (Figure 1). The target sites (85) embrace water bodies with different hydroperiods (permanent vs temporary), and origin (natural, semi-natural and artificial) (Suppl. material 1, Table S1).

From a biogeographical point of view, this area is part of the Italo-Tyrrhenian Province and of the Sicilian Subprovince (Brullo et al. 1995), encompassing the "Drepano-Panormitano" (Trapani, Palermo, Trabia and Sicani Mts), "Madonita" (Madonie Chain), and the "Agrigentino" (Chalky-sulphurous series of Sicily inlands; Musarella et al. 2018) districts, and various other intermediate (e.g., Bosco Granza, Rocca Busambra) or border (e.g., "Sciare of Mazara", Carboj River and the Mandrarossa Stream catchments) areas.

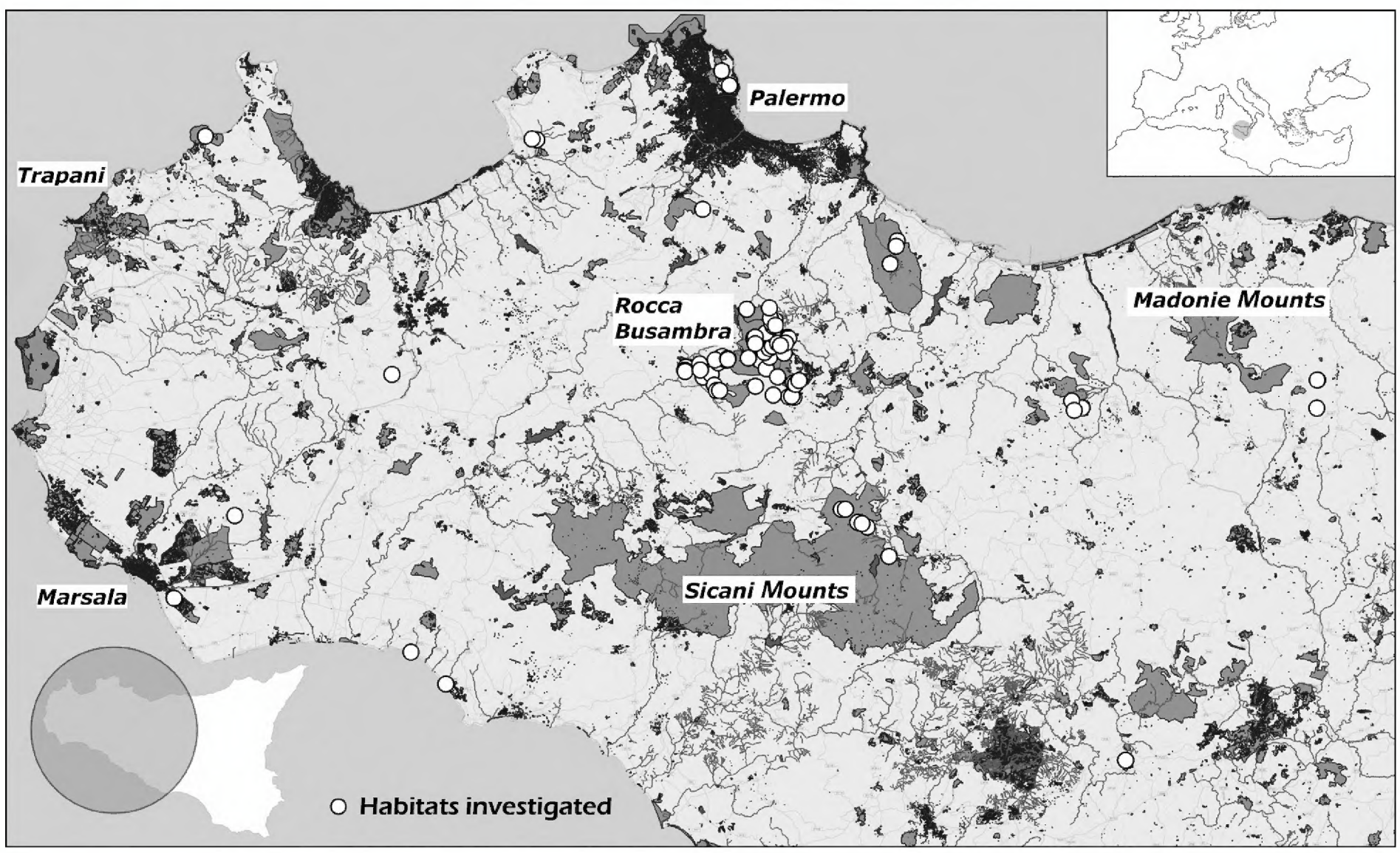

Figure 1. The study area with distribution of investigated habitats (see Supplementary material 1: Table S1).

Most of studied biotopes fall within the Tyrrhenian orographic ridge, characterized by limestone, limestone-dolomite, and dolomite substrates whose formation dates back from the Mesozoic to Tertiary periods. Moving from the Madonie Chain towards west, altitudes tend to decrease up to the Trapani Mts (from 1979 m a.s.l. of the Pizzo Carbonara to the 751 m a.s.l. of the Monte Erice), with internal peaks including the Rocca Busambra (1613 m a.s.l) and the Sicani Mts with the Monte Cammarata (1578 m a.s.l) (Figure 1). The Agrigento and Nisseno sectors are instead part of an evaporite complex which includes soils of the Chalky-sulphurous Formation of the upper Miocene (Musarella et al. 2018).

The study area is characterized by a Mediterranean macroclimate, with three different subtypes: xeric-oceanic, pluviseasonal-oceanic and Temperate/submediterranean (Rivas-Martínez 2004). As detailed by Gianguzzi et al. (2015b), adopting the classification by Rivas-Martínez and Rivas-Saenz (1996-2020), the following thermotypes may be recognized: infra-Mediterranean (with an annual average temperature of 18-20 °C), thermo-Mediterranean (16-18 °C); meso-Mediterranean (13-16 °C) and supra-Mediterranean (8-13 °C). Concerning the rainfall regimes, the study area (Caldarella et al. 2013a; Gianguzzi et al. 2011a, 2011b, 2014a, 2014b, 2015a, 2015b, 2016; Gianguzzi and Bazan 2019; Guarino and Pasta 2017; Romano et al. 2006; etc.) falls within the following ombrotypes: dry (with an annual average precipitation of 350-600 mm), subhumid (600-1000 mm), and humid (> 1000 mm).

Phytosociological, synecological and syndinamical analyses

The aquatic vegetation was studied following the phytosociological method of the Zurich-Montpellier school (Braun-Blanquet 1964), as later modified by other authors (e.g., Rivas-Martínez 2005; Biondi 2011). 147 unpublished relevés were carried out in the period between 2012-2020, subsequently compared with the few phytosociological relevés available in literature. The relevés matrix, transformed according to the Van der Maarel (1979) scale, was converted into a distance matrix by the vegdist function of the vegan package (Oksanen et al. 2020) using the Euclidean distance as an index of distance. Subsequently, the distance matrix was subjected to cluster analysis using the *hclus* function of *R* (R Core Team, 2021) applying the Ward method. Subsequent arrangement of phytosociological tables (see Tables 1-14) has allowed the identification of the plant communities that have been classified according to the phytosociological syntaxonomic system, and the "International Code of Phytosociological Nomenclature" (Theurillat et al. 2020).

The nomenclature of the syntaxa of higher rank (alliances, orders, and classes) is in accordance with Mucina et al. (2016), with some references also to the "Vegetation Prodrome of Italy" (Biondi et al. 2014). The attribution of the coenoses at the association level o follows mainly Rivas-Martínez et al. (2001, 2002) and Chytrý (2011), as well as other specific works duly cited in the text. The identification, nomenclature and biological forms of the plant species follow Pignatti (2017-2019). Biological forms are abbreviated as follows: I nat = free-floating hydrophyte; I rad = rooted hydrophyte; G rhiz = rhizomatous geophyte; H scap/caesp/bienn = scapose/caespitose/biennial hemicryptophyte; T scap/caesp/rept = scapose/caespitose/reptant hemicryptophyte.

For each investigated community, the list of *Diagnostic taxa (% constancy)*, *Syntaxonomic note*s, a *Short description* with information on *Syndynamism* and *Bioclimate in Sicily*, *Synchorology*, and *Local distribution* were provided.

Results and Discussion

The dendrogram obtained from the cluster analysis (Figure 2) allowed the identification of 4 plant communities belonging to the *Lemnetea* class (Table 15) and 11 to the *Potamogetonetea* class (Table 16), respectively, as detailed in the syntaxonomical scheme.

The clusters of associations are closely overlapped each other at the upper levels, as many species are largely shared between relevés of the various communities investigated. This is mainly due to the strong spatial overlap of coenoses that tend to colonize thin concentric strips along the shoreline of the studied water bodies. Despite this, cluster fidelity is 97%, as only 4 relevés belonging to two clusters (10, *Ranunculetum aquatilis*, and 12 *Lemno-Callitrichetum obtusangulae*) have been subjectively classified exclusively based on physiognomy and dominant species.

1. *LEMNETUM MINORIS* von Soó 1927 (Tables 1 and 15)

Diagnostic taxa (% constancy) – *Lemna minor* L. (100%, dominant).

Syntaxonomic note – Concerning the communities dominated by *L. minor* L., several authors agree in identifying a basic unit with an "association value" (Géhu and Pedrotti 1992; Schratt 1993; Rivas-Martínez et al. 2001). However, other authors, including Müller (1977), Scoppola (1982), and Pott (1995), do not find the ground for the definition of a specific syntaxon due to the wide ecological and biogeographical values of this species (Sburlino et al. 2004). The *Lemnetum minoris* is rather common in Europe including the Mediterranean area (Ninot et al. 2000; Brullo et al. 2002; Šumberová 2011a; Felzines 2012; Zervas et al. 2020). The dominant species develops in several habitat types, often forming mono-paucispecific stands (Maiorca et al. 2007; Sburlino et al. 2004; Šumberová 2011a; Bolpagni and Piotti 2015; Spampinato et al. 2019). The association can be found on marginal zone of still and nutrient-rich freshwater bodies, in very shallow sectors (Zervas et al. 2020).

Short description – Acropleustophytic aquatic community dominated by *L. minor*, able to form more or less dense free-floating stands in temporary or permanent ponds, which hardly exceed 1.5 meters in depth. This community

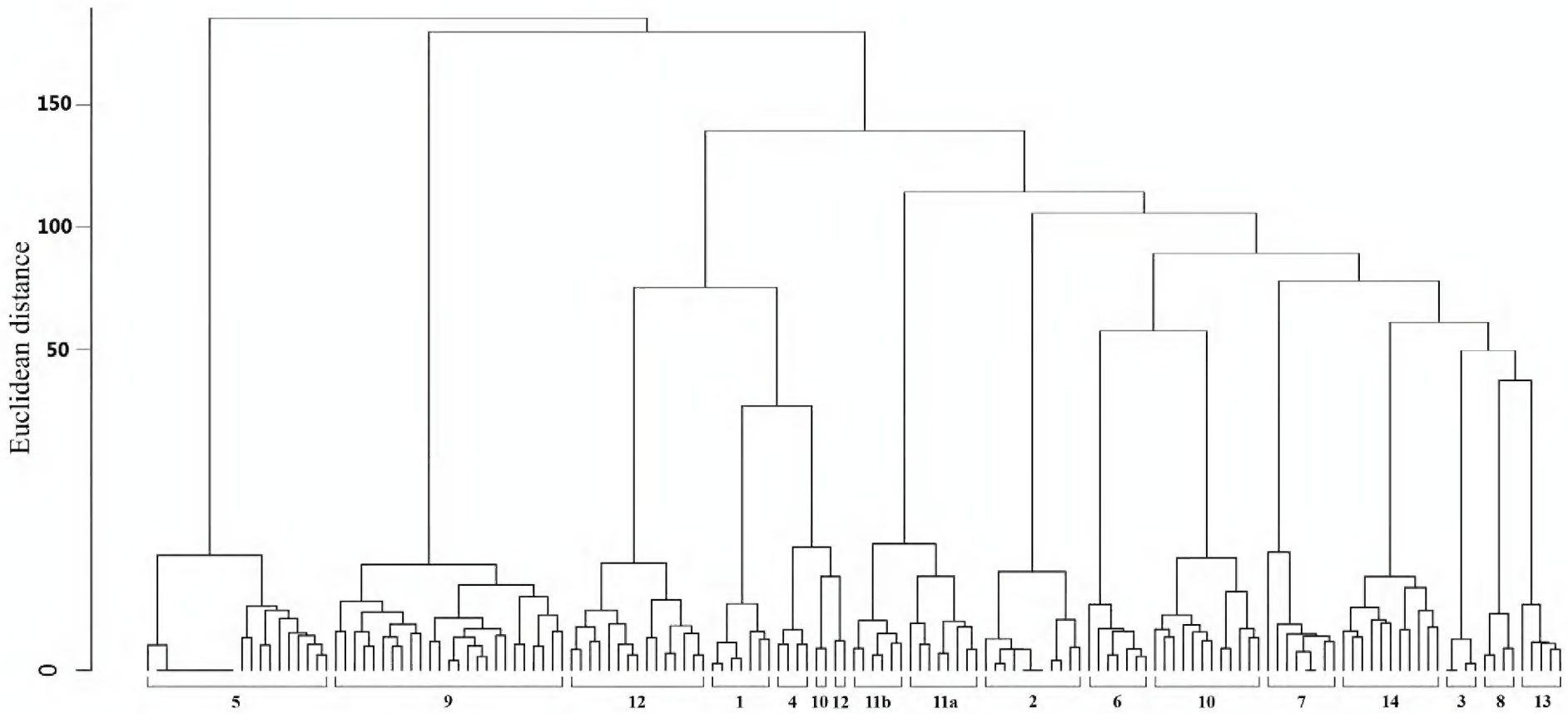

Figure 2. Dendrogram obtained from the cluster analysis of relevés showing the associations of the Lemnetea and Potamogetonetea classes: 1) *Lemnetum minoris*; 2) *Lemnetum gibbae*; 3) *Lemna minuta* community; 4) *Potamogetono-Ceratophylletum submersi*; 5) *Potamogetonetum natantis*; 6) *Potamogetonetum pusilli*; 7) *Potamogetonetum pectinati*; 8) *Groenlandietum densae*; 9) *Ranunculetum rionii*; 10) *Ranunculetum aquatilis*; 11a) *Ranunculetum peltati* subass. *typicum*; 11b) *Ranunculetum peltati* subass. *ranunculetosum rionii*; 12) *Lemno-Callitrichetum obtusangulae*; 13) *Callitriche stagnalis* community; 14) *Junco bufonii-Ranunculetum omiophylli*.

is typical of sunny, stagnant water bodies, sheltered from the wind, and tends to interpenetrate with other aquatic coenoses. In the studied area, its growth optimum is in late spring, whereas it tends to regress in the presence of summer drying events, and stationing of livestock.

Syndynamism – Pioneer community which tends to be invasive, limiting the growth of submerged hydrophytes. At Gorgo Lungo (Godrano, PA) the association is in contact with the *Potamogetono-Ceratophylletum submersi* (Table 4)

Bioclimate in Sicily – Mediterranean pluviseasonal-oceanic (meso-Mediterranean subhumid/humid).

Synchorology – *L. minor* is a subcosmopolitan species, with an oceanic climatic optimum, which is present in North America, Europe, Africa, and Western Asia (Landolt 1986). *L. minor* communities have a wide distribution and are quite widespread in continental Italy (Brullo et al. 2001; Sburlino et al. 2004) and large islands (Biondi and Bagella 2005). In Sicily, they were recognized on the Nebrodi and Sicani Mts (Brullo et al. 1994; Marino et al. 2005), and in the Trapani (Guarino and Pasta 2017) and Palermo (at Bosco Granza; Gristina and Marcenò 2009) surroundings.

Local distribution – In the study area, this association is quite rare; it was detected at the Bosco Ficuzza (Gorgo Lungo, Margiazzo del Vallone Arcere, Contrada Sovarita and Contrada Cannitello), and Bosco Granza at Bomes Lakes (Figure S3d) and Portella Granza.

2. *LEMNETUM GIBBAE* Miyawaki et J. Tüxen 1960 (Tables 2 and 15)

Diagnostic taxa (% constancy) – *Lemna gibba* L. (100%, dominant).

Syntaxonomic note – Due to the very poor and constant composition, the stands dominated by *L. gibba* L. are generally ascribed to the *Lemnetum gibbae* (Sburlino et al. 2004), typical of stagnating eutrophic to hypertrophic waters, often subjected to direct anthropic disturbance and/or pollution (Scoppola 1982; Ninot et al. 2000; Sburlino et al. 2004; Šumberová 2011a; Lastrucci et al. 2014).

Short description – Acropleustophytic aquatic association dominated by *L. gibba*. It forms dense free-floating populations, which tend to cover the entire surface of small ponds. This association is typical of weakly flowing environments, artificial basins, and ditches used for watering livestock, up to 150 cm deep, sunny and/or partially shaded. The association's growth optimum is in late spring and it tolerates summer water stress conditions. Based on the present relevés, two distinct aspects have been described: one represented by monospecific or strictly paucispecific stands; and a second one characterized by a richer presence of hydrophytes, even if with very low cover values.

Bioclimate in Sicily – Mediterranean xeric-oceanic/Mediterranean pluviseasonal-oceanic (from infra-Mediterranean dry to meso-Mediterranean subhumid/humid).

Syndynamism – This association is a pioneering assemblage, sometimes able to act as invasive. Due to the

Table 1. *Lemnetum minoris* von Soó 1927.

Life form	Relevé number	1	2	3	4	5	6	7	Presence
	Altitude (m a.s.l.)	827	827	530	530	776	908	863	
	Plot size (mq)	1.5	1.5	1.5	1	1	1.5	1.5	
	Total cover (%)	90	80	80	90	80	80	80	
	Height of vegetation (cm)	3	3	4	4	3	3	3	
	N° species for relevé	4	4	5	5	3	4	4	
	Localities (see Suppl. material 1, Table S1)	43	43	65	65	31	78	76	
	Char. of association and upper units								
I nat	*Lemna minor* L.	5	4	5	4	4	4	4	7
	***Potamogetonetea* units**								
I rad	*Callitriche obtusangula* Le Gall	1	.	1	1	.	1	1	5
I rad	*Ranunculus rionii* Lagger	.	.	.	.	1	.	.	1
	Other species								
G rhiz	*Glyceria notata* Chevall.	1	+	1	1	+	1	1	7
H scap	*Mentha aquatica* L.	.	.	1	+	.	+	1	4
	Chara sp.	1	1	.	.	.	.	.	2
T scap	*Ranunculus ophioglossifolius* Vill.	.	.	1	+	.	.	.	2
G rhiz	*Equisetum telmateia* Ehrh.	.	1	.	.	.	.	.	1

Table 2. *Lemnetum gibbae* Miyawaki et J. Tüxen 1960.

Life Form	Relevé number	1	2	3	4	5	6	7	8	9	10	11	Presence
	Altitude (m a.s.l.)	5	248	248	615	615	464	472	890	890	738	738	
	Plot size (mq)	1	1	1	1	1	1	1	1	1	1	1	
	Total cover (%)	80	80	90	100	100	100	100	100	100	90	90	
	Height of vegetation (cm)	1	0,5	0,5	1	1	-	1	5	5	2	3	
	N° species for relevé	2	1	1	2	1	1	1	5	5	3	4	
	Localities (see Suppl. material 1, Table S1)	79	82	82	30	30	81	4	37	37	72	72	
	Char. of association												
I nat	*Lemna gibba* L.	5	3	4	5	5	5	5	5	5	5	5	11
I nat	*Lemna minor* L.	.	.	.	.	.	.	.	1	1	.	.	2
	***Potamogetonetea* units**												
I rad	*Ranunculus aquatilis* L.	.	.	.	.	.	.	.	1	+	1	+	4
I rad	*Callitriche obtusangula* Le Gall	.	.	.	.	.	.	.	1	1	.	.	2
I rad	*Potamogeton trichoides* Cham. et Schltdl.	.	.	.	.	.	.	.	.	.	.	1	1
	Other species												
H caesp	*Alopecurus aequalis* Sobol.	.	.	.	.	.	.	.	1	+	+	1	4
G rhiz	*Bolboschoenus maritimus* (L.) Palla	1	.	.	.	.	.	.	.	.	.	.	1
H scap	*Mentha pulegium* L.	.	.	.	+	.	.	.	.	.	.	.	1

progressive eutrophication of waters with the advance of season (e.g., progressive concentration of solutes), in conjunction with higher summer water temperatures, it tends to locally replace the *Lemnetum minoris* of which can be considered as a seasonal vicariant.

Synchorology – This association is rather common in Italy and it was also largely reported for the Italian territory, including the Mediterranean regions (e.g., Maiorca et al. 2007, 2020; Minissale and Spampinato 1990; Sburlino et al. 2004). In Sicily it was recognized by several authors (Abbadessa et al. 2005; Marino et al. 2005; Giardina et al. 2007), with records for the Nisseno (Marcenò and Raimondo 1977), and Etnean areas (Minissale and Spampinato 1990), the Catania (Cambria 2012), Trapani (Gianguzzi and La Mantia 2009) and Palermo sourroundings (Gianguzzi and La Mantia 2004; Gristina and Marcenò 2009).

Local distribution – It is a rather rare association. It was found at the Bosco Ficuzza area (Case Cuttitta, Gorgo Cerro and Gorgo Lungo), at the Monte Palmeto near Carini (PA), and at the mouth of the Mandrarossa Stream along the Agrigento coast (Menfi, AG).

3. *LEMNA MINUTA* community (Tables 3 and 15)

Diagnostic taxa (% constancy) – *Lemna minuta* Kunth (100%, dominant).

Syntaxonomic note – *L. minuta* Kunth is an alien species native to the temperate and subtropical America (Banfi and Galasso 2010), locally considered as invasive as in many other Italian regions (Galasso et al. 2018). From a phytosociological point of view, in Italy this species forms communities attributed at different associations such as *Azollo filiculoidis-Lemnetum minuscolae* Felzines & Loiseau 1991 or *Lemnetum minuto-gibbae* Liberman Cruz, Pedrotti & Venanzoni 1988, even if some authors consider these assemblages as a basal phytocoenon (Sburlino et al. 2004; Viciani et al. 2020 and references therein).

Short description – Acropleustophytic aquatic community dominated by *L. minuta*. It isable to form dense free-floating populations that can spread rapidly and cover the entire surface of the colonized water bodies, with a growth optimum in spring. It occurs in shaded environments, even if it is well suited to conditions of high insolation, and hypereutrophy. Indeed, this association is

frequently found in artificial habitats, or deeply impacted water bodies, with depths up to 1.8 m. Our relevés show monophytic or very poor stands, showing an extremely impoverished aspect of the *Lemnetum minuto-gibbae* association. Within this community in the study area another alien species such as *Paspalum distichum* L. is frequently recorded.

Bioclimate in Sicily – Mediterranean xeric-oceanic (thermo-Mediterranean dry/subhumid).

Syndynamism – *L. minuta* acts as a pioneering *taxon*, often becoming invasive.

Synchorology – In Northern and Central Italy (Sburlino et al. 2004; Ceschin et al. 2016), the species has shown a recently rapid spread. In southern Italy it has also started to spread by colonising lakes with high naturalness (Spampinato et al. 2019). Before the present work, the only reports for Sicily concerned two small ponds at the Monte Pellegrino, near Palermo (Marrone and Naselli Flores 2011).

Local distribution – It is a rather rare community; it was confirmed for the Monte Pellegrino at the Gorgo of Santa Rosalia (Suppl. material 2, Figure S1b) and Cozzo della Grattalora, and in the Trapani surroundings, near the city of Mazara del Vallo.

Table 3. *Lemna minuta* community.

	Relevé number	1	2	3	4	
	Altitude (m a.s.l.)	392	392	234	4	
Life	Plot size (mq)	2	2.5	1	1	
Form	Total cover (%)	90	100	100	100	
	Height of vegetation (cm)	3	3	3	3	
	N° species for relevé	2	2	1	1	Presence
	Localities (see Suppl. mat. 1, Table S1)	73	73	74	84	
	Characteristic species					
I nat	*Lemna minuta* Kunth	5	5	5	5	4
	Other species					
G rhiz	*Paspalum distichum* L.	+	1	.	.	2

Table 4. *Potamogetono-Ceratophylletum submersi* Pop 1962.

	Relevé number	1	2	3	4	
	Altitude (m a.s.l.)	890	890	890	890	
Life	Plot size (mq)	2	2,5	5	5	
form	Total cover (%)	90	100	100	100	
	Height of vegetation (cm)	4	4	70	80	
	N° species for relevé	7	5	6	7	Presence
	Localities (see Suppl. mat. 1, Table S1)	37	37	37	37	
	Char. of association					
I rad	*Ceratophyllum submersum* L.	3	3	5	4	4
	Char. of upper units					
I nat	*Lemna minor* L.	5	5	3	2	4
I nat	*Lemna gibba* L.	+	+	+	+	4
	***Potamogetonetea* units**					
I rad	*Callitriche obtusangula* Le Gall	1	+	2	1	4
I rad	*Ranunculus aquatilis* L.	1	1	+	1	4
I rad	*Ranunculus rionii* Lagger	.	.	.	+	1
	Other species					
H caesp	*Alopecurus aequalis* Sobol.	1	.	+	+	3
G rhiz	*Glyceria notata* Chevall.	+	.	.	.	1

4. *POTAMOGETONO-CERATOPHYLLETUM SUBMERSI* Pop 1962 (Tables 4 and 15; Suppl. material 2, Figure S1c)

Diagnostic taxa (% constancy) – *Ceratophyllum submersum* L. (100%, dominant).

Syntaxonomic note – *C. submersum* L. is a very rare species, both in Sicily and in Italy in general (Lastrucci et al. 2019a). Due to the rarity of this species, only scarce phytosociological data are available, at least for Italy. According to the phytosociological databases LISY (Bracco et al. 2007) and VegItaly (Landucci et al. 2012), communities dominated by *C. submersum* have been reported only for few wetlands in Northern Italy (Gerdol et al. 1979; Piccoli 1998; Pedrotti 2003). According to Šumberová (2011a), *C. submersum*-dominated communities can be attributed to the association *Potamogetono-Ceratophylletum submersi* Pop 1962 typical of shallow, well-isolated, and warm in summer ponds, with remarkable water level variations (see also Hrivnák 2002). The association can also include the presence of lemnids.

Short description – Submerged community with ceratophyllid habit dominated by *C. submersum*. It is typical of shallow ponds, where the species tends to occupy the entire water body. It tolerates some degree of shading and can be favoured by the presence of a thin layer of floating pleustophytes (e.g., *Lemna minor* and *L. gibba*), as well as by a progressive seasonal eutrophication of waters and high summer temperatures. Its growth optimum is in late spring.

Bioclimate in Sicily – Mediterranean pluviseasonal-oceanic (meso-Mediterranean subhumid).

Syndynamism – In the study area, the association is in close contact with the *Lemnetum minoris*, which it replaces in the deeper sectors of the Gorgo Lungo pond, where this species tends to spread into the wettest sectors of the helophytic belts dominated by *Sparganium erectum* L. and *Schoenoplectus lacustris* (L.) Palla.

Synchorology – In Sicily, *C. submersum* is quite rare: the Gorgo Lungo near Godrano (PA) is the only ascertained population for the western sector of Sicily so far (Lastrucci et al. 2019a).

Local distribution – Gorgo Lungo (Godrano, PA).

5. *POTAMOGETONETUM NATANTIS* Hild 1959 (Tables 5 and 16; Suppl. material 2, Figure S1g)

Diagnostic taxa (% constancy) – *Potamogeton natans* L. (100%, dominant).

Syntaxonomic note – In Sicily, and in the Nebrodi Mountains in particular, *P. natans* L. was considered a characteristic species of two different associations: the *Utricolario-Potametum natantis* Raimondo, Marino & Schicchi 2011, that belongs to the order *Utricularietalia* Den Hartog & Segal 1964 (Raimondo et al. 2011), and the *Polygono-Potametum natantis* Soò (1927) 1964, as reported by Brullo et al. (1994). This latter appears as a rather complex vegetation type, with two different as-

Table 5. *Potamogetonetum natantis* Hild 1959.

	Relevé number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
	Altitude (m a.s.l.)	1002	950	1285	925	478	368	378	652	790	503	1323	950	953	953	707	692	757	741	868	868	
Life	Plot size (mq)	10	10	8	8	10	10	10	10	15	10	6	6	5	5	4	5	10	5	5	5	
Form	Total cover (%)	90	80	80	100	80	85	90	80	100	100	100	100	100	100	100	80	100	100	90	90	
	Height of vegetation (cm)	250	200	100	150	250	250	200	250	100	150	50	100	150	150	150	100	150	150	120	120	
	N° species for relevé	2	1	1	1	1	1	1	1	1	1	3	3	3	3	4	2	3	3	3	2	
	Localities (see Suppl. material 1, Table S1)	20	77	75	12	13	15	14	21	60	47	16	77	23	23	26	59	64	63	19	19	fresence
	Char. of association																					
I rad	*Potamogeton natans* L.	5	5	5	5	5	5	5	5	5	5	5	5	4	5	5	4	5	5	5	5	20
	***Potamogetonetea* units**																					
I rad	*Ranunculus rionii* Lagger	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	2	1	+	1	5
I rad	*Potamogeton pusillus* L.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	2
I rad	*Ranunculus peltatus* Schrank	.	.	.	.	.	.	.	.	.	.	.	.	2	1	.	.	.	.	.	.	2
I rad	*Callitriche obtusangula* Le Gall	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1
I rad	*Potamogeton trichoides* Cham. et Schltdl.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	1
I rad	*Ranunculus aquatilis* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	1
I rad	*Callitriche brutia* Petagna	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	1
	Other species																					
G rhiz	*Glyceria notata* Chevall.	.	.	.	.	.	.	.	.	.	.	2	1	.	.	.	.	.	1	.	.	3
G rhiz	*Typha angustifolia* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	2
I nat	*Lemna minor* L.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	1
G rhiz	*Phragmites australis* (Cav.) Trin. ex Steud.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	1

pects: a first one dominated by *Persicaria amphibia* (L.) Delarbre, and a second one dominated by *P. natans*. In the study area, however, *P. amphibia* is rather rare and never plays a clear physiognomic role. Based on this, we prefer to refer the recorded *P. natans* coenoses to a new association for Sicily, the *Potamogetonetum natantis* Hild 1959. This community is typical of mostly mesotrophic, but also oligotrophic to eutrophic shallow water bodies (in the range 20–100 cm), with still or slowly moving waters (Šumberová 2011b). Some criticisms remain, in any case, respect to the attribution of this association to the alliance level. Several authors (e.g., Šumberová 2011b) ascribed this association to the *Potamogetonion* alliance, while others to the *Nymphaeion* alliance (e.g., Venanzoni & Gigante 2000; Jarolímek et al. 2008; Ferrez et al. 2011). Since *P. natans* contributes only marginally to form submerged stands, we are led to classify this association into the *Nymphaeion* alliance, that includes communities dominated by floating-leaved hydrophytes. In the study area, the association shows both monophytic and more diversified aspects.

Short description – Rhizophytic community dominated by *P. natans*, often monospecific, in which other hydrophytes belonging to the *Potamogetonetea* are occasionally present. The coenosis is typical of permanent habitats (including artificial ones) with depths greater than 80 cm (and up to 4 m), with oligo-mesotrophic to mesotrophic waters and subjected to wide summer water variations. *P. natans* tends to form quite dense stands (> 80% in coverage), colonizing the innermost, permanent sectors of water bodies.

Bioclimate in Sicily – Mediterranean pluviseasonal-oceanic and Temperate/submediterranean (from meso-Mediterranean to supra-Mediterranean subhumid-humid).

Syndynamism – This association is in close contact with other associations of the *Potamogetonetea* class (*Potamogetonetum pusilli*, *Ranunculetum peltati*, *Lemno-Callitrichetum obtusangulae*) and algal assemblages (*Chara* spp.), as well as of the marginal helophytic communities of the *Phragmito-Magnocaricetea* Klika in Klika & Novák 1941 class.

Synchorology – P. natans-dominated communities are rather common in Europe (Meriaux 1983; Doll 2008; Görs 1992; Schratt 1993; Pott 1995; Sburlino et al. 2008; ecc.) and in Italy, where they are reported for several wetlands from northern to southern regions (Aita et al. 1979; Montanari and Guido 1980; Gerdol and Piccoli 1980; Corbetta and Pirone 1989; Gerdol and Tomaselli 1993, 1997; Buchwald 1994; Piccoli 1998; Bracco et al. 2000; Tomaselli and Bernardo 2006; Tomaselli et al. 2006; Sburlino et al. 2008; Venanzoni and Gigante 2000; Lastrucci et al. 2004; Bolpagni and Piotti 2015). In Sicily, this association was recognized for the Nebrodi (Gianguzzi 2006; Raimondo et al. 2011) and Madonie Mts (Sortino et al. 1977; Brullo et al. 1994).

Local distribution – This association was found in both natural and artificial ponds lied in the hilly-mountain sector, scattered in several reservoirs of the Bosco Ficuz-

za and Rocca Busambra area, on the Sicani Mountains at Monte Carcaci and further east at the Bosco Granza, at the Madone al Gorgo di Pollicino (Suppl. material 2, Figure S3c) and at the Pietra Giordano, as previously recorded by Sortino et al. (1977).

6. *POTAMOGETONETUM PUSILLI* von Soó 1927 (Tables 6 and 16; Suppl. material 2, Figure S1f)

Diagnostic taxa (% constancy) – *Potamogeton pusillus* L. (100%, dominant).

Syntaxonomic note – *P. pusillus* L. often shows a certain ecological amplitude being able to establish in freshwater habitats with both standing and weakly flowing waters (Preston 1995). In Italy, the communities of *P. pusillus* are generally ascribed to a basal phytocoenon (Biondi et al. 1997, 2004; Piccoli 1998; Tomaselli and Bernardo 2006, Lastrucci et al. 2008; Sburlino et al. 2008). However, in lentic habitats, such as small pools (Lastrucci et al. 2012) or natural lakes (Landucci et al. 2011), the *P. pusillus* communities show a greater compositional constancy that justifies the attribution to an association (*Potamogetonetum pusilli*).

Short description – The association is typical of mesotrophic to eutrophic water bodies. It occupies a wide range of depths (0.5–3.0 m), often colonizing disturbed habitats, or representing early successional stages of pond evolution (Šumberová 2011b). In the study area, *P. pusillus* is often associated to other sporadic hydrophytes, such as *Ranunculus aquatilis* L. and *Callitriche brutia* Petagna. The *Potamogetonetum pusilli* stands are rather dense (> 90% in coverage) and colonize depths of about 80-100 cm, occupaying the intermediate vegetation belt between central, deeper sectors and shorelines. It has its growth optimum in spring.

Bioclimate in Sicily – Mediterranean pluviseasonal-oceanic (meso-Mediterranean subhumid-humid).

Syndynamism – In the study area, this association is mainly represented by paucispecific stands and replace the Ranunculion aquatilis at deeper waters. In the innermost sectors of ponds, it spreads into others *Potamogetonetea* class units and algal assemblages (*Chara* spp.). Along the littorals, it is in close contact with the helophytic consortia of the *Phragmito-Magnocaricetea* class.

Synchorology – *P. pusillus* is a species with a circumboreal distribution (Preston 1995). Communities dominated by *P. pusillus* are reported for Germany (Pott 1995), Poland (Nowak et al. 2007), and various regions of Italy, such as Friuli Venezia Giulia, (Sburlino et al. 2008), Lombardy (Bolpagni 2013), Veneto (Pingitore et al. 2013), Emilia Romagna (Biondi et al. 1997; Piccoli 1998), Tuscany (Lastrucci et al. 2008), Umbria (Landucci et al. 2011), and Calabria (Tomaselli and Bernardo 2006). In Sicily, this species had been detected for the Nebrodi Mts, in the frame of the following associations: *Utricularietum australis* Müller et Görs 1960 (Brullo et al. 1994), and *Utricularo-Potametum natantis* (Raimondo et al. 2011).

Local distribution – This association has been found only in a few locations, both on flyschyoid and carbonate substrates. At the Rocca Busambra area, it is very rare, found only in the small lake locally called "r'u zù Rusulìnu" (Godrano, PA). Conversely, this association is much widespread at the Pizzo Cane Reserve, at the Pizzo Selva a Mare, as well as at Cozzo Valdaro and Contrada Randino.

7. *POTAMOGETONETUM PECTINATI* Carstensen ex Hilbig 1971 (Tables 7 and 16)

Diagnostic taxa (% constancy) – *Potamogeton pectinatus* L. (100%, dominant).

Syntaxonomic note – Widespread association, reported for several European countries, including some Mediterranean areas and Sicily (Géhu and Biondi 1988; Baldoni and Biondi 1993; Ninot et al. 2000; Venanzoni and Gigante 2000; Brullo et al. 2002; Ferrez et al. 2011; Raimondo et al. 2011; Šumberová 2011b; Zervas et al. 2020). It is often mono- or paucispecific, typical of freshwater and brackish habitats, from eutrophic to hypertrophic, polluted waters, with high turbidity and anoxic conditions (Baldoni and Biondi 1993; Ceschin and Salerno, 2008; Landucci et al. 2011; Azzella et al. 2013). Coenoses characterized by *P. pectinatus* L. and *Fontinalis antipyretica* Hedw. were reported for Crete Island by Gradstein & Smittenberg (1977).

Short description – Rhizophytic community dominated by *P. pectinatus*, sporadically associated with other rooted hydrophytes. It is typical of estuary environments with weakly flowing waters, deep water reservoirs (even over 3 m of depth), and semi-permanent, natural habitats where the dominant taxon tends to form dense stands (> 80% coverage). The growth optimum is in the spring-summer period. In the study area, we noted the coexistence of monospecific stands of *P. pectinatus* alongside richer assemblages in species, including algae of the genus *Chara*. The presence of a non-negligible contribution of macroalgae to *P. pectinatus* stands was previously highlighted by Gradstein and Smittenberg (1977) for Crete Islands.

Bioclimate in Sicily – Mediterranean xeric-oceanic/Mediterranean pluviseasonal-oceanic (from infra-Mediterranean dry to meso-Mediterranean subhumid/humid).

Syndynamism – It colonizes the deepest sectors of the colonized water bodies, coming into contact with other coenoses of the *Potamogetonetea* class and algal assemblages (dominated by *Chara* spp.). Along littorals, this association tends to spread into the helophytic communities of the *Phragmito-Magnocaricetea* class.

Synchorology – *P. pectinatus* is a cosmopolitan species, typical of fresh- and brackish waters on all continents, except Antarctica. The *Potamogetonetum pectinati* was described for Germany (Carstensen 1955), and it is reported for other various European countries (Hilbig 1971; Schubert et al. 1995; Matuszkiewicz 2005; Šumberová 2011a), as well as for continental Italy (Sburlino et al. 2008), and Italian largest islands (Brullo et al. 2001; Biondi and Bagella 2005). In Sicily, it is widespread both in coastal areas, in aquatic habitats with low salinity, and mainland (Bartolo et al. 1982; Spampinato and Sciandrello 2013). It

Table 6. *Potamogetonetum pusilli* von Soó 1927.

	Relevé number	1	2	3	4	5	6	7	
	Altitude (m a.s.l.)	638	707	678	678	620	707	620	
Life	Plot size (mq)	5	5	4	5	5	5	5	
Form	Total cover (%)	100	100	100	100	100	100	90	
	Height of vegetation (cm)	35	35	30	30	40	30	45	
	N° species for relevé	4	4	4	4	5	5	4	
	Localities (see Suppl. material 1, Table S1)	6	26	1	1	5	26	5	Presence
	Char. of association								
I rad	*Potamogeton pusillus* L.	5	5	5	5	5	5	5	7
	***Potamogetonetea* units**								
I rad	*Ranunculus aquatilis* L.	.	1	2	1	+	1	1	6
I rad	*Callitriche brutia* Petagna	.	+	.	.	.	+	.	2
I rad	*Potamogeton natans* L.	.	1	.	.	.	.	.	1
	Other species								
G rhiz	*Glyceria notata* Chevall.	2	.	+	1	1	+	+	6
G rhiz	*Eleocharis palustris* (L.) Roem. et Schult.	1	.	.	.	+	+	+	4
	Chara sp.	.	.	+	+	.	.	.	2
G rhiz	*Juncus articulatus* L.	2	.	.	.	+	.	.	2

Table 7. *Potamogetonetum pectinati* Carstensen ex Hilbig 1959.

	Relevé number	1	2	3	4	5	6	7	8	
	Altitude (m a.s.l.)	464	1002	543	566	578	2	547	637	
Life	Plot size (mq)	20	10	10	10	10	7	5	10	
form	Total cover (%)	100	90	100	100	80	100	100	100	
	Height of vegetation (cm)	-	250	200	250	200	150	200	250	
	N° species for relevé	4	5	3	2	1	1	3	4	
	Localities (see Table S1)	81	20	58	53	7	80	55	52	Presence
	Char. of association									
I rad	*Potamogeton pectinatus* L.	4	5	5	5	5	5	5	5	8
	***Potamogetonetea* units**									
I rad	*Ranunculus aquatilis* L.	3	.	1	.	.	.	.	.	2
I rad	*Potamogeton trichoides* Cham. et Schltdl.	.	1	.	.	.	.	.	+	2
I rad	*Potamogeton natans* L.	.	+	.	.	.	.	.	.	1
I rad	*Ranunculus rionii* Lagger	.	+	.	.	.	.	.	.	1
	Other species									
	Chara sp.	4	1	.	.	.	.	1	.	3
G rhiz	*Phragmites australis* (Cav.) Trin. ex Steud.	.	.	.	+	.	.	.	+	2
G rhiz	*Typha angustifolia* L.	.	.	.	.	.	.	+	+	2
	Cladophora sp.	2	.	.	.	.	.	.	.	1
G rhiz	*Glyceria notata* Chevall.	.	.	+	.	.	.	.	.	1

is mentioned for some river mouths, and lentic habitats in the Hyblean sector (Bartolo et al. 1982; Spampinato and Sciandrello 2013), in the Trapani (Brullo and Ronsisvalle 1975) and in the Nisseno areas (Marcenò and Raimondo 1977; Brullo and Sciandrello 2006; Sciandrello 2009).

Local distribution – In the study area, it was found in different artificial reservoirs, near Rocca Busambra (Contrada Casale, Contrada Cicio, and Contrada Alpe Cucco), on the Sicani Mountains (at the Gorgo di Sant'Andrea; Figure S3b) and at the mouth of the Carboj River along the Agrigento coast.

8. *GROENLANDIETUM DENSAE* Segal ex Schipper et al. in Schaminée et al. 1995 (Tables 8 and 16)

Diagnostic taxa (% constancy) – *Groenlandia densa* (L.) Fourr. (100%, dominant).

Synon. – *Groenlandietum densae* Bolós 1957 (phantom); *Groenlandietum densae* Segal 1965 (*nom. nud.*, art. 2b); *Potamogeton* Korneck 1969 (art. 3c).

Syntaxonomic note – Community of oligo-mesotrophic water bodies, and limestone substrates (Ferrez et al. 2011), distributed in Central and Southern Europe (Brullo et al. 1994). Several *G. densa*-associations have been described for the Iberian Peninsula (Loidi et al. 1997), both for flowing waters [*Ranunculo trichophylli-Groenlandietum densae* (Kohler et al. 1974) Passarge 1994], and lentic habitats (*Groenlandio densae-Zannichellietum peltatae* Velayos, Carrasco & Cirujano 1989). This latter unit is replaced by the *Potametum denso-nodosi* O. Bolòs 1957 in habitats with greater nutrient availability (Melendo et al. 2003).

Short description – Rhizophytic community dominated by *G. densa*, only sporadically associated with other hydrophytes, such as *Callitriche obtusangula* Le Gall., occurs predominantly in sunny, permanent habitats, where develops medium coverage stands (up to 80%). This species prefers groundwater-dependent ecosystems, and spring waters which contribute to mitigate the excessive heating of water in summer. It preferably colonises littorals (up to

Table 8. *Groenlandietum densae* Segal ex Schipper et al. in Schaminée et al. 1995.

	Relevé number	1	2	3	4	
	Altitude (m a.s.l.)	950	950	964	964	
Life	Plot size (mq)	4	5	1	1	
form	Total cover (%)	80	80	80	80	
	Height of vegetation (cm)	30	30	40	35	
	N° species for relevé	3	4	4	5	
	Localities (see Suppl. mat. 1, Table S1)	77	77	8	8	Presence
	Char. of association and alliance					
I rad	*Groenlandia densa* (L.) Fourr.	4	4	4	4	4
	Char. of *Potamogetonion* and upper units					
I rad	*Callitriche obtusangula* Le Gall	1	1	.	.	2
	Other species					
G rhiz	*Glyceria notata* Chevall.	+	1	2	1	4
	Chara sp.	.	.	+	1	2
G rhiz	*Juncus articulatus* L.	.	.	+	1	2
H scap	*Lythrum junceum* Banks et Sol.	.	+	.	.	1
H scap	*Mentha aquatica* L.	.	.	.	+	1

80-100 cm), on both flyschioide and carbonate sediments waterproofed by silty-clayey deposits.

Bioclimate in Sicily – Mediterranean pluviseasonal-oceanic and Temperate/submediterranean (from meso-Mediterranean subhumid to supra-Mediterranean subhumido-humid).

Syndynamism – *G. densa* communities are closely associated to several aquatic plant associations colonizing the permanent sectors of water bodies (cl. *Potamogetonetea*), as well as algal assemblages (*Chara* ssp.), as recorded in the Nebrodi Mts (Guarino et al 2019), and helophytic belts (cl. *Phragmito-Magnocaricetea*).

Synchorology – *G. densa* is a Eurosiberian species (Pignatti 2017–2019). In Sicily, it is reported for the Nebrodi (Barbagallo et al. 1979; Brullo et al. 1994; Gianguzzi 2006; De Castro et al. 2008, 2015a, 2015b; Guarino et al. 2019) and Sicani Mts (Gianguzzi et al. 2007).

Local distribution – A small population has been recorded in a reservoir located along the south side of the Monte Carcaci (Castronovo di Sicilia, PA); a second location is in a small wetland at the Bosco Granza (Sclafani Bagni, PA).

9. *RANUNCULETUM RIONII* Hejný et Husák in Dykyjová et Květ 1978 (Tables 9 and 16; Suppl. material 2, Figure S2a)

Diagnostic taxa (% constancy) – *Ranunculus rionii* Lagger (100%, dominant).

Syntaxonomic note – The association is typical of shallow, eutrophic, and often salt-rich, warm ponds (Sumberová 2011b). Our stands can be attributed to the *Ranunculetum rionii*, an association reported for the first time in Italy by Lastrucci et al. (2019b) for the Acquato Lake, in Tuscany. *R. rionii* Lagger was recorded as new species for Sicily by Bartolucci et al. (2021). The populations of *R. rionii* of Western Sicily show a certain morphological affinity with *R. trichophyllus* Chaix, from which they differ for the presence of smaller and hairless achenes, and smaller petals.

Short description – Paucispecific aquatic community with a distinct myriophyllid habit, dominated by *R. rionii*, which tends to form compact and continuous belts along the outer edges of semi-permanent or ephemeral ponds characterized by strong seasonal water level variations. In the study area, this association was found in small ponds, even temporary ones, situated both on flyscioid substrates waterproofed by sub-alkali clay deposits, but also on limestone and calcarenites. The association's growth optimum is in late spring.

Bioclimate in Sicily – Mediterranean xeric-oceanic and Mediterranean pluviseasonal-oceanic (from thermo-Mediterranean dry to meso-Mediterranean subhumid/humid).

Syndynamism – This association is often in contact with other *Potamogetonetea* and algal assemblages (*Chara* spp.), whereas along littorals it spreads into helophytic belts, as testified by the presence of several helophytes with high frequency values in the collected relevés.

Synchorology – *R. rionii* is a species with wide distribution in North Africa, Europe, and Central-Western Asia (Wiegleb et al. 2017); despite this, the *Ranunculetum rionii* is mainy known for Eastern Europe (Korotkov et al. 1991; Dubyna 2006; Kubalová 2009; Hrivnák and Csiky 2009) and France (Felzines 2016).

Local distribution – It has been recognized in several small ponds (both natural and artificial), distributed around the Sicani Mts, Rocca Busambra, Palermo Mts (at the Gorgo di Rebuttone; Altofonte – Suppl. material 2, Figure S1a), on the south side of the Monte Palmeto (Carini), and further east on the limestone platforms of Mazara del Vallo (at the Garufi plain; Suppl. material 2, Figure S2e).

10. *RANUNCULETUM AQUATILIS* Géhu 1961 (Tables 10 and 16; Suppl. material 2, Figure S2b)

Diagnostic taxa (% constancy) – *Ranunculus aquatilis* L. (100%; dominant).

Taxonomic and Syntaxonomic note – The presence of *R. aquatilis* in Italy is rather debated. The species was reported with several regional *lacunae* for the flora of Italy (Pignatti 1982; Conti et al. 2005), until Desfayes (2008, 2011) proposed to exclude it from the entire Italian territory. This proposal was accepted by Bartolucci et al. (2018) but not by the editors of the second edition of the "Italian Flora" by Pignatti (2017–2019) that lists this species as present in Italy. Even if the *R. aquatilis* group is a very critical group, in our opinion, *R. aquatilis* is recognizable in the study area and distinguished from *Ranunculus peltatus* Schrank for various characters such as the length of peduncles, the leaf margin shape, length of the petals and the morphology of nectar pits, as reported by many European determination keys (Pignatti 1982; Cook 1986; Pizarro 1995; Wiegleb et al. 2017). From a phytosociological point of view, *R. aquatilis*-assemblages are attributed to the association *Ranunculetum aquatilis* Géhu 1961, growing on clear, stagnant or slow-running, sunny, neutro-basophilous and nutrient-rich waters, on silty-clayey

Table 9. *Ranunculetum rionii* Hejný et Husák in Dykyjová et Květ 1978.

	Relevé number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
	Altitude (m a.s.l.)	863	130	891	1071	1002	863	863	868	652	652	784	516	745	745	585	773	996	487	709	787	787	704	704	595	235	
Life	Plot size (mq)	5	5	4	5	10	4	5	5	5	10	5	10	5	5	6	15	2	2	3	7	4	5	5	8	5	
Form	Total cover (%)	100	80	95	100	100	100	100	100	100	100	100	100	100	100	95	100	85	100	95	100	100	100	100	100	100	
	Height of vegetation (cm)	50	25	50	130	50	100	100	60	40	60	100	60	90	70	100	40	50	50	90	50	60	40	40	30	25	
	N° species for relevé	4	3	4	3	4	4	4	5	5	4	3	4	3	3	4	2	3	2	3	5	6	5	5	5	5	
	Localities (see Suppl. material 1, Table S1)	9	85	34	32	20	18	18	19	21	21	54	56	62	62	70	61	25	33	69	57	57	2	2	35	3	Presence
	Char. of association																										
I rad	*Ranunculus rionii* Lagger	5	5	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	25
	***Potamogetonetea* units**																										
I rad	*Potamogeton pectinatus* L.	.	.	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3
I rad	*Potamogeton natans* L.	.	.	.	.	+	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3
I rad	*Callitriche obtusangula* Le Gall	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.	2
I rad	*Potamogeton pusillus* L.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	1
I rad	*Ranunculus aquatilis* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	1
	Othes species																										
G rhiz	*Glyceria notata* Chevall.	.	.	.	+	.	.	.	.	.	.	+	.	+	1	1	1	1	.	2	2	1	2	1	2	2	14
H scap	*Mentha pulegium* L.	.	.	.	.	+	.	.	.	1	.	.	+	.	.	+	.	.	.	.	+	1	.	.	1	1	8
I rad	*Alisma lanceolatum* With.	.	1	.	.	.	1	+	+	1	.	.	.	.	.	.	.	.	.	.	1	2	.	.	.	.	7
G rhiz	*Juncus articulatus* L.	.	.	1	.	.	.	+	.	+	1	.	.	.	.	+	.	.	.	.	.	+	.	.	.	.	6
	Chara sp.	1	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	1	5
H scap	*Mentha aquatica* L.	.	.	1	.	.	+	.	+	.	.	.	.	+	1	.	.	.	.	.	.	.	.	.	.	.	5
G rhiz	*Eleocharis palustris* (L.) R. et S.	.	.	.	.	.	.	.	+	.	1	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	4
G rhiz	*Typha angustifolia* L.	.	.	.	.	.	+	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	3
G rhiz	*Juncus effusus* L.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
T rept	*Coronopus squamatus* (Forssk.) Asch.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	1	.	2
G rhiz	*Bolboschoenus maritimus* (L.) Palla	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	+	.	.	.	.	2
H scap	*Oenanthe fistulosa* L.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
G rhiz	*Persicaria amphibia* (L.) Delarbre	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1
G rhiz	*Paspalum distichum* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	1
H scap	*Rumex crispus* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
H scap	*Ranunculus angulatus* C. Presl	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1

Table 10. *Ranunculetum aquatilis* Géhu 1961.

Life Form	Relevé number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Presence
	Altitude (m a.s.l.)	797	800	543	707	704	678	678	474	474	842	738	643	890	890	
	Plot size (mq)	3	3	6	5	3	8	6	5	5	3	5	5	6	4	
	Total cover (%)	100	100	100	100	90	90	100	95	100	100	100	100	100	100	
	Height of vegetation (cm)	35	25	35	100	30	30	35	50	45	20	130	60	60	70	
	N° species for relevé	6	3	3	5	6	4	4	5	5	6	5	3	6	6	
	Localities (see Suppl. material 1, Table S1)	27	28	58	26	2	1	1	39	39	42	72	29	37	37	
	Char. of association															
I rad	*Ranunculus aquatilis* L.	5	4	5	5	4	4	5	4	5	4	5	5	4	5	14
	***Potamogetonetea* units**															
I rad	*Callitriche stagnalis* Scop.	.	.	.	.	.	.	.	1	1	2	3	2	.	.	5
I rad	*Ranunculus rionii* Lagger	1	.	.	.	1		.	1	+	.	.	.	.	.	4
I rad	*Potamogeton pusillus* L.	.	.	.	2	.	1	1	.	.	.	.	.	.	.	3
I rad	*Callitriche brutia* Petagna	.	.	.	+	.	.	.	.	.	.	1	.	.	.	2
I rad	*Callitriche obtusangula* Le Gall	.	.	.	.	.	.	.	.	.	.	.	.	2	3	2
I rad	*Potamogeton pectinatus* L.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	1
I rad	*Potamogeton natans* L.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	1
	Others species															
G rhiz	*Glyceria notata* Chevall.	1	2	1	+	2	2	1	.	.	2	1	1	1	1	12
H scap	*Mentha pulegium* L.	1	.	.	.	+	.	+	.	.	+	.	.	.	.	4
G rhiz	*Eleocharis palustris* (L.) Roem. et Schult.	.	.	.	1	1	.	.	1	1	.	.	.	.	.	4
H caesp	*Alopecurus aequalis* Sobol.	.	.	.	.	.	.	.	.	.	.	1	.	1	+	3
G rhiz	*Juncus articulatus* L.	+	1	.	.	.	.	.	.	.	.	.	.	.	.	2
I rad	*Alisma lanceolatum* With.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	2
I rad	*Ceratophyllum submersum* L.	.	.	.	.	.	.	.	.	.	.	.	.	2	1	2
I nat	*Lemna minor* L.	.	.	.	.	.	.	.	.	.	.	.	.	2	2	2
H scap	*Rumex pulcher* L.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	1
H bienn	*Jacobaea erratica* (Bertol.) Fourr.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	1
T scap	*Ranunculus ophioglossifolius* Vill.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	1
H scap	*Rumex conglomeratus* Murray	.	.	.	.	.	.	.	.	.	+	.	.	.	.	1

bottom, occasionally subject to desiccation or eutrophication (Buchwald 1994; Passarge1992).

Short description – Batrachid community, with a clear predominance of *R. aquatilis*, which is associated with *Gliceria notata* Chevall. and other sporadic *taxa* of the *Potamogetonetea* class (*Callitriche stagnalis* Scop., *C. brutia* and *C. obtusangula*). It is typical of sunny ponds, characterized by strong seasonal water variations, situated on flyschoid substrates, but in some cases also on calcareous substrates. This association contributes to form a continuous belt along the external edges of colonized water bodies, at depths between about 50 cm and shores, therefore well adapted to the rapid drying of temporary Mediterranean ponds. The association's growth optimum is in late spring.

Bioclimate in Sicily – Mediterranean pluviseasonal-oceanic (meso-Mediterranean subhumid/humid).

Syndynamism – This association is in close contact with submerged algal assemblages (*Chara* spp.) or with coenoses of the *Potamogetonetea* and *Lemnetea* classes. Often, the association forms actual transitional communities towards deeper vegetation belts (Rels 13–14, table 10). Along the outer edges of the colonized water bodies, this association is progressively replaced by helophytic belts of the *Phragmito-Magnocaricetea* class, and sometimes it spreads into the *Isoëto-Nanojuncetea* Br.-Bl. & Tüxen ex Westhoff, Dijk & Passchier 1946 communities in habitats subjected to rapid seasonal water variations and the progressive drying of sediments.

Synchorology – *R. aquatilis* is a subcosmopolitan species, with a wide Euro-Asian distribution, as well as in North Africa and North America. In Italy, associations dominated by *R. aquatilis* have been reported mainly for Central Italy (e.g., Biondi et al. 1999). As put in evidence by several authors (Géhu and Meriaux 1983; Passarge 1992), one of the main issues related to the correct recognition of this association depends on the fact that many authors do not separate the assemblages dominated by *R. aquatilis* and *R. peltatus*, respectively. Consequently, the *Ranunculetum aquatilis* is often considered as a macro-association to which populations of both species can be attributed (see also Sumberová 2011b). Nevertheless, Géhu and Meriaux (1983) highlighted how in France the two species differentiate two distinct associations, ecologically and geographically vicariant. In particular, the *Ranunculetum aquatilis* shows a wide ecological amplitude, and a greater preference for organic and nutrient rich waters. In the study area, a clear distinction between the typical habitats of these two coenoses has been recognized. *R. aquatilis* prefers water bodies located at higher altitudes (hilly and sub-mountain horizons) and shows a more mesophilic character. Conversely, *R. peltatus* is also found at low-altitude locations (200–250 m s.l.m), even in coastal areas of North-Western Sicily.

Local distribution – The association has been detected in several hilly and submontane water bodies, both of natural and artificial origin, permanent and semi-permanent (with a hydroperiod of 9–10 months). It is distributed in the foothills north of the Rocca Busambra (e.g., Gorgo

Lungo, Gorgo dei Palermitani, Gorgo Cerro), at altitudes between 738 and 890 m a.s.l., in the Trabia (at the Gorgo di Pizzo Selva a Mare) and in the Palermo Mts (at the Gorgo di Rebuttone).

11. *RANUNCULETUM PELTATI* Horst, Krausch & Müller-Stoll 1966 em. Weber-Oldecop 1969
subass. *TYPICUM* (Table 11a rels 1–7; tab. 16; Suppl. material 2, Figure S2c)

Diagnostic taxa (% constancy) – *Ranunculus peltatus* Schrank (100%, dominant).

Syntaxonomic note – *R. peltatus* (Suppl. material 2, Figure S2d) shows a high adaptability to different ecological conditions (Garbey et al. 2004), implying that this species may differentiated more than one community (see also Lastrucci et al. 2007). The association *Ranunculetum peltati* is typical of small, clear lentic water bodies, with depths not exceeding 80–100 cm. These habitats can be moderately rich in nutrients, subjected to summer desiccation and livestock impacts, however the *Ranunculetum peltati* is particularly sensitive to pollution and shading (Passarge 1992). Two subassociations, the subass. *typicum* and the subass. *potamogetonetosum* were identified and typified by Passarge (1992). The *Ranunculetum peltati* was also reported for the Mediterranean area by Gradstein and Smittenberg (1977). In addition, for the oligotrophic, neutro-acidophilous deep standing and cold waters of temperate and Mediterranean siliceous areas of the Iberian Peninsula, the association *Callitricho brutiae-Ranunculetum peltati* Pizarro & Rivas Martínez 2004 was described. This latter association is considered as a geosynvicariant of the *Ranunculetum peltati*, and it was recently reported for some wetlands in Tuscany by Lastrucci et al. (2007) due the presence of some characteristic species of the association, such as *C. brutia* and *Myriophyllum alterniflorum* DC. In the study area, however, *C. brutia* is rather rare and only rarely found in the coenoses dominated by *R. peltatus*. Therefore, it seemed more appropriate to assign the Sicilian assemblages to the *Ranunculetum peltati*. Furthermore, the ecological conditions observed in Sicily seem rather far from those recorded for Spain. Here, the studied water bodies are not characterized by cold waters, and their depth is rather low. Based on this, we identified a new subassociation differentiated from *R. rionii* and species indicating high water fluctuations, such as *Oenanthe fistulosa* L. and *Alisma lanceolatum* With.

Short description – Batrachid community with a clear predominance of *R. peltatus*, only occasionally associated with other hydrophytes. It is typical of ponds characterized by strong seasonal water level variations, situated on carbonate substrates, with oligo-mesotrophic waters. This coenosis prefers the sunniest sectors of colonized habitats, sometimes extending over the entire surface of reservoirs/ponds, developing in these conditions submerged stems up to depths greater than 2 m. With the progressive and rapid lowering of the water level, *R. peltatus* tends to go up to the emerged banks tolerating the initial phases of seasonal desiccation. Its growth optimum is in the late spring.

Bioclimate in Sicily – Mediterranean pluviseasonal-oceanic (from thermo-Mediterraean dry to meso-Mediterranean subhumid/humid).

Syndynamism – This association is continuous with other coenoses of the *Potamogetonetea* class and sub-

Table 11. *Ranunculetum peltati* subass. *typicum* Horst, Krausch & Müller-Stoll 1966 em. Weber-Oldecop 1969 (a: Rels 1–7) and subass. *ranunculetosum rionii* subass. nova (b: Rels 8–14) (**holotypus* rel. 13).

		a							b							
	Relevé number	1	2	3	4	5	6	7	8	9	10	11	12	13*	14	
	Altitude (m a.s.l.)	777	248	248	197	197	934	953	953	925	925	863	863	859	859	
Life	Plot size (mq)	4	5	5	5	4	4	5	5	5	5	3	4	5	5	
form	Total cover (%)	100	100	100	100	100	100	100	100	100	95	90	100	100	100	
	Height of vegetation (cm)	45	45	40	35	35	40	60	40	30	30	35	35	25	20	
	N° species for relevé	4	4	3	4	4	5	5	5	5	5	7	6	5	6	
	Localities (see Suppl. material 1, Table S1)	71	82	82	83	83	11	23	23	40	40	9	9	38	38	
	Char. subass. *Typicum*															
I rad	*Ranunculus peltatus* Schrank	5	4	5	4	4	5	5	5	5	4	5	5	5	5	14
	Char. subass. *ranunculetosum rionii*															
I rad	*Ranunculus rionii* Lagger	.	.	.	.	.	.	.	+	1	2	1	1	2	2	7
H scap	*Oenanthe fistulosa* L.	.	.	.	.	.	1	.	.	+	1	+	1	1	+	7
I rad	*Alisma lanceolatum* With.	.	.	.	.	.	.	.	.	.	.	+	+	2	+	4
	***Potamogetometea* units**															
I rad	*Potamogeton trichoides* Cham. et Schltdl.	.	.	.	.	.	.	1	+	.	.	.	.	.	.	2
I rad	*Callitriche brutia* Petagna	2	.	.	.	.	.	.	.	.	.	.	.	.	.	1
I rad	*Potamogeton natans* L.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	1
	Othes species															
G rhiz	*Glyceria notata* Chevall.	2	2	1	2	1	+	+	+	1	2	+	+	1	+	14
G rhiz	*Eleocharis palustris* (L.) Roem. et Schult.	.	.	.	+	1	1	+	+	.	.	+	+	.	.	7
I nat	*Lemna gibba* L.	1	2	2	.	.	.	.	.	.	.	.	.	.	.	3
H scap	*Mentha pulegium* L.	.	1	.	.	.	.	.	.	+	+	.	.	.	.	3
T scap	*Myosotis sicula* Guss.	.	.	.	+	1	.	.	.	.	.	.	.	.	.	2
H scap	*Galium debile* Desv.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	1
H scap	*Mentha aquatica* L.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	1
H scap	*Veronica anagallis-aquatica* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1

Presenc

merged algal assemblages (*Chara* spp.); along littorals, it tends to be replaced by amphibian vegetation often dominated by *G. notata*.

Synchorology – *R. peltatus* is a European species restricted to the temperate and southern areas of Europe, North Africa, and West Asia (Wiegleb et al. 2017).

Local distribution – It is present in several small ponds (both natural and artificial) located along the southern side of the Rocca Busambra (at the Piano Guddemi; Godrano, PA), at the Monte Carcaci (Castronovo di Sicilia, PA), and further west in the Trapani surroundings (at the Pantani di Anguillara; Calatafimi), and at the Gorgo di Monte Cofano (Custonaci; Gianguzzi and La Mantia 2009, originally reported as *Ranunculetum baudotii* Br.-Bl. in Br.-Bl., Roussine & Négre 1952).

RANUNCULETOSUM RIONII subass. nov. (Table 11b rels 8–14 - *holotypus* rel. 13; tab. 16)

Diagnostic taxa (% constancy) – *Ranunculus rionii* Lagger (100%, dominant), *Oenanthe fistulosa* L. (> 80%).

Short description – This subassociation differs from the typical aspect of the *Ranunculetum peltati* mainly because it colonizes littorals (with depths up to 50–60 cm) and muddy sediments. The community is characterized by the constant presence of *R. rionii* and *O. fistulosa*, accompanied with a certain frequency by *A. lanceolatum*. It has the growth optimum in spring, and it prefers higher altitude habitats than the association *typicum*.

Bioclimate in Sicily – Mediterranean pluviseasonal-oceanic (meso-Mediterranean subhumid/humid).

Local distribution – It is present in some ponds distributed in the core sector of the study area, at altitudes between 850 and 950 m a.s.l., along the southern side of the Rocca Busambra (contrade Marosa and Guddemi), and at the Sicani Mts (at the Gorgo di Carcaci).

12. *LEMNO-CALLITRICHETUM OBTUSANGULAE* (Philippi 1978) Passarge 1992 (Tables 12 and 16; Suppl. material 2, Figure S1d)

Diagnostic taxa (% constancy) – *Callitriche obtusangula* Le Gall (100%, dominant), *Lemna minor* L. (> 35%).

Syntaxonomic note – *C. obtusangula* may form stands both in running and in stagnant waters. According to several authors (e.g., Meriaux and Verdevoye 1983; Brullo et al. 1994; Sburlino et al. 2008), in running waters its typical association is the *Callitrichetum obtusangulae* Seibert 1962, belonging to the *Batrachion fluitantis* Neuhäusl 1959 alliance. For several wetlands of Nebrodi Mts, Brullo et al. (1994) described a very peculiar and complex community ascribed to the *Glycerio-Callitrichetum obtusangulae* Brullo, Minissale & Spampinato 1994. This association is differentiated by *C. obtusangula*, *C. brutia* var. *hamulata* (Kütz. ex W.D.J. Kock) Lansdown and *C. stagnalis*, as well as by the presence with rather high frequencies of amphibian taxa such as *Glyceria spicata* Guss., *Peplis portula* L., and *Alopecurus aequalis* Sobol., besides a large group of aquatic species. The coenoses dominated by *Callitriche* genus in the study area exhibit some ecological similarities with those described by Brullo et al. (1994), however they differ strongly in the floristic assemblage. Here, only *C. obstusangula* has been found, whereas *G. spicata* is absent and replaced by *G. notata*, which cannot be considered as a good differential *taxon* because it is present in almost all the coenoses here reported, besides being the most frequent species in the study area (55% of frequency

Table 12. *Lemno-Callitrichetum obtusangulae* (Philippi 1978) Passarge 1992.

	Relevé number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
	Altitude (m a.s.l.)	1323	1326	769	950	868	783	783	487	772	855	530	530	936	908	863	890	890	
Life	Plot size (mq)	2	3	3	4	3	5	5	2	10	5	8	6	3	3	3	5	4	
form	Total cover (%)	100	100	90	90	100	100	100	100	70	90	100	100	100	90	100	100	100	
	Height of vegetation (cm)	30	50	20	40	20	5	50	25	35	25	30	30	15	40	35	50	60	
	N° species for relevé	3	2	3	3	4	2	3	4	5	4	6	6	4	4	4	5	3	
	Localities (see Suppl. mat. 1, Table S1)	16	17	41	77	19	22	22	33	68	36	65	65	44	78	76	37	37	Presence
	Char. of association																		
I rad	*Callitriche obtusangula* Le Gall	5	5	5	5	5	5	5	5	4	5	5	5	5	5	5	4	5	17
I nat	*Lemna minor* L.	.	.	.	.	.	.	.	.	.	.	1	1	.	1	1	3	2	6
	***Potamogetonetea* units**																		
I rad	*Ranunculus rionii* Lagger	.	.	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	2
I rad	*Potamogeton natans* L.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
I rad	*Ranunculus aquatilis* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1
	Othes species																		
I rad	*Glyceria notata* Chevall.	1	.	2	1	.	.	.	.	2	2	2	1	1	1	2	.	.	10
H scap	*Mentha aquatica* L.	.	.	.	.	+	.	.	.	.	.	+	+	1	+	1	.	.	6
H scap	*Mentha pulegium* L.	.	.	1	.	.	+	+	1	.	1	.	.	.	.	.	.	.	5
T scap	*Ranunculus ophioglossifolius* Vill.	.	.	.	.	.	.	.	.	1	2	1	+	.	.	.	.	.	4
T scap	*Ranunculus muricatus* L.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	2
H scap	*Rumex conglomeratus* Murray	.	.	.	.	.	.	.	.	.	.	1	+	.	.	.	.	.	2
I rad	*Ceratophyllum submersum* L.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	2
H scap	*Lythrum junceum* Banks et Sol.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	1
I rad	*Alisma lanceolatum* With.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	1
G rhiz	*Eleocharis palustris* (L.) Roem. et Schult.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	1
H scap	*Rumex pulcher* L.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	1
I rad	*Ranunculus omiophyllus* Ten.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	1
H caesp	*Alopecurus aequalis* Sobol.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	1

in the relevés matrix). Furthermore, given the importance of *L. minor* in differentiating the communities of *C. obstusangula* in the study area, it seems most appropriate to attribute these coenosis to the *Lemno-Callitrichetum obtusangulae*, also reported for the northern Italy by Sburlino et al. (2008). Passarge (1992) placed this association in the alliance *Lemno-Callitrichion* Passarge 1992, that currently has been placed in synonim with the *Ranunculion aquatilis* (Mucina et al. 2016). The *Lemno-Callitrichetum obtusangulae* is typical of summer-warm waters, rich in nutrient, tolerating drying periods, eutrophication, and slight salinity, but fearing cold winters and anthropogenic pollution (Passarge 1992).

Short description – Aquatic vegetation dominated by *C. obtusangula*, with the frequent presence of *L. minor*. This community is typical of small, semi-permanent water bodies lied on quartzarenitic substrates, with high levels of clay or sometimes with sandy sediments. It prefers muddy bottoms, and conditions of partial sunshine, growing at depths not exceeding 60 cm, and tolerating slightly eutrophic conditions. The association's growth optimum is in late spring.

Bioclimate in Sicily – Mediterranean pluviseasonal-oceanic and Temperate/submediterranean (from meso-Mediterranean to supra-Mediterranean subuhmid-humid).

Syndynamism – Towards the deepest part of the water body sectors, this association is in contact with other kinds of *Potamogetonetea* and *Lemnetea* vegetation, while along littoral it spreads into the *Phragmito-Magnocaricetea* belts.

Synchorology – The association is distributed in the temperate-sub-Atlantic regions of Europe (Passarge 1992), while in Italy it has been previously reported only for the Veneto region (Sburlino et al. 2008).

Local distribution – Ponds located in the northern foothills of the Rocca Busambra, at altitudes between 500 and 650 m a.s.l., in the surroundings of Godrano (Gorgo Lungo, Gorgo Pizzo Campana, Case Franco, Vallone Frattina and Coda di Riccio), Monreale (Zotta Frascino and Vallone Arcere), and Marineo (Cozzo Bileo and Sovarita). Further east, it is found in the Sclafani Bagni area (at Bosco Granza and Lake Bomes; PA), as well as at the Madonie Mts (at Pietra Giordano; Geraci Siculo, PA).

13. *CALLITRICHE STAGNALIS* community (Tables 13 and 16; Suppl. material 2, Figure S3e)

Diagnostic taxa (% constancy) – *Callitriche stagnalis* Scop. (100%, dominant), *Ranunculus omiophyllus* Ten. (80%).

Syntaxonomic note – In Italy *C. stagnalis* differentiates communities belonging both to the *Ranunculion fluitantis* (e.g., Buchwald 1994; Ceschin and Salerno 2008) and the *Ranunculion aquatilis* (e.g., Baldoni and Biondi 1993; Brullo et al. 1994; Brullo et al. 2001; Lastrucci and Becattini 2008; Lastrucci et al. 2015) alliances. This confirms the ecological amplitude of this species, able to form stands in both running and stagnant waters. From a syntaxonomic point of view, the *C. stagnalis*-stands are frequently ascribed to a *Callitriche stagnalis* phytocoenon, less frequently to the *Callitrichetum stagnalis* Segal 1965 (Ceschin and Salerno 2008). However, for South Italy, peculiar coenoses dominated by this species have been described. Brullo et al. (1994) classified the *C. stagnalis* stands recorded at the Nebrodi Mts as a new subassociation (subass. *callitrichetosum stagnalis*) of the *Glycerio spicatae-Callitrichetum obtusangulae* Brullo, Minissale & Spampinato 1994. At the Aspromonte Mt (Calabria), instead, a peculiar association, ascribed to the *Ranunculion aquatilis* alliance, dominated by *C. stagnalis*, *Ranunculus ophioglossifolius* Vill., *P. portula*, *Juncus articulatus* L. and *P. natans* has been described as *Ranunculo ophioglossifolii-Callitrichetum stagnalis* Brullo, Scelsi, Spampinato 2001 (Brullo et al. 2001).

Table 13. *Callitriche stagnalis* community.

	Relevé number	1	2	3	4	5	
	Altitude (m a.s.l.)	1030	801	1028	898	738	
Life	Plot size (mq)	5	2	2	5	5	
form	Total cover (%)	90	90	85	80	95	
	Height of vegetation (cm)	15	10	10	10	10	
	N° species for relevé	4	4	4	3	7	
	Localities (see Suppl. material 1, Table S1)	48	24	49	45	72	Presence
	Diff. species						
I rad	*Callitriche stagnalis* Scop.	4	4	4	5	4	5
	***Potamogetonea* units**						
I rad	*Ranunculus omiophyllus* Ten.	1	1	1	1	.	4
I rad	*Ranunculus aquatilis* L.	.	.	.	.	1	1
	Othes species						
I rad	*Glyceria notata* Chevall.	2	2	3	2	3	5
I rad	*Veronica anagallis-aquatica* With.	1	.	.	.	.	1
H scap	*Lythrum junceum* Banks et Sol.	.	1	.	.	.	1
H scap	*Mentha pulegium* L.	.	.	+	.	.	1
H caesp	*Alopecurus aequalis* Sobol.	.	.	.	.	1	1
H scap	*Oenanthe aquatica* (L.) Poir.	.	.	.	.	1	1
I nat	*Lemna gibba* L.	.	.	.	.	+	1
T scap	Ranunculus ophioglossifolius Vill.	.	.	.	.	+	1

Short description – Aquatic vegetation dominated by *C. stagnalis*, in which *Ranunculus omiophyllus* Ten. and *G. notata* are frequently found, often showing high cover-abundance values. This kind of vegetation colonizes the margins of small, permanent water bodies, fed by groundwater, or semi-permanent ponds with depths not exceeding 10–15 cm, with short summer drying phases. The community seems to prefer wet habitats with muddy bottoms, sunlight, and oligotrophic to slightly eutrophic waters/sediments (in ponds subject to livestock grazing/trampling), situated on quartz-sand substrates. It has the growth optimum in spring.

In a small pond of the study area (Gorgo Cerro along the northern side of the Rocca Busambra; table 12, rel. 5), an extremely impoverished aspect of the *Ranunculo ophioglossifolii-Callitrichetum stagnalis* Brullo, Scelsi, Spampinato 2001 has been recorded. Accordingly, the presence of this association in Sicily could be hypothesized. Further investigations will be necessary to verify this preliminary insight.

Bioclimate in Sicily – Mediterranean pluviseasonal-oceanic (meso-Mediterranean subhumid/humid).

Syndynamism – *C. stagnalis* forms stands in contact with other *Potamogetonetea* coenoses, in particular with the *Junco bufonii-Ranunculetum omiophylli*, compared to which tends to occupy more inundated zones. It represents a transitional phase towards wet vegetation of highly, marginal flooded sectors of ponds.

Local distribution – Small wet habitats on the northern side of the Rocca Busambra near the Bosco Ficuzza.

14. *JUNCO BUFONII-RANUNCULETUM OMIOPHYLLI ass. nov.* (Table 14 - *holotypus* rel. 8; tab. 16; Suppl. material 2, Figure S3f)

Diagnostic taxa (% constancy) – *Ranunculus omiophyllus* Ten. (100%, dominant), *Juncus bufonius* L. (> 80 %).

Syntaxonomic note – *R. omiophyllus* is mainly distributed in the Atlantic Europe, from North- Spain to British Islands, but with an extension in the Mediterranean, from North Africa to Sicily, and Southern Italy (Pizarro 1995; Pignatti 2017–2019). According to Rivas-Martinéz et al. (2001, 2002), *R. omiophyllus* is a characteristic taxon of the *Ranunculion omiophyllo-hederacei* Rivas-Martinéz et al. 2002, a peculiar alliance characterized by rooted stoloniferous helophytic ranunculids with floating leaves, as *Ranunculus hederaceus* L. or *R. omiophyllus*, (Rivas-Martinéz et al. 2002). For Spain, two associations dominated by *R. omiophyllus* have been described: the *Ranunculetum omiophylli* Braun-Blanquet & Tüxen (1943) 1952, and the *Myosotido stoloniferae-Ranunculetum omiophylli* Rivas-Martínez et al. 2002. The first association includes, besides *R. omiophyllus* (= *Ranunculus lenormandi* F.W. Schultz.), other species such as *Potamogeton oblongus* Viv., *Juncus bulbosus* L., *C. brutia* var. *hamulata*. Conversely, the second one is characterized by *Myosotis stolonifera* (DC.) J. Gay ex Leresche & Levier, *Montia fontana*

Table 14. *Junco bufonii-Ranunculetum omiophylli ass. nov.* (**holotypus* rel. 8).

	Relevé number	1	2	3	4	5	6	7	8*	9	10	11	
	Altitude (m a.s.l.)	708	710	856	842	936	1015	898	801	797	1030	1028	
Life	Plot size (mq)	3	3	2	2	3	2	5	3	5	3	2	
form	Total cover (%)	100	90	80	85	100	85	70	75	100	90	85	
	Height of vegetation (cm)	15	15	10	10	20	10	10	10	15	15	10	
	N° species for relevé	6	5	5	6	5	9	5	6	6	8	7	
	Localities (see Suppl. material 1, Table S1)	66	67	51	42	44	50	45	24	46	48	49	Presence
	Char. of association												
I rad	*Ranunculus omiophyllus* Ten.	5	5	5	5	5	5	4	5	4	5	5	11
T caesp	*Juncus bufonius* L.	2	1	2	1	.	2	3	1	.	+	1	9
	***Isoëto-Nanojuncetea* units**												
T caesp	*Poa infirma* Kunth	1	1	+	1	.	+	1	1	.	.	.	7
H scap	*Mentha pulegium* L.	1	.	.	.	.	.	2	1	.	.	1	4
T scap	*Isolepis cernua* (Vahl.) Roem. et Schult.	.	.	.	.	.	+	.	.	.	.	.	1
T scap	*Trifolium micranthum* Viv.	.	.	.	.	.	.	.	1	.	.	.	1
T scap	*Ranunculus muricatus* L.	.	.	.	.	.	.	.	.	1	.	.	1
T scap	*Ranunculus angulatus* C. Presl	.	.	.	.	.	.	.	.	.	+	.	1
	***Callitr. hamulatae-Ranunculetalia aquatilis* units**												
I rad	*Callitriche stagnalis* Scop.	.	.	.	.	.	.	1	2	2	1	+	5
I rad	*Callitriche obtusangula* Le Gall	.	.	.	.	1	+	.	.	.	.	.	2
I rad	*Ranunculus aquatilis* L.	.	.	.	1	.	.	.	.	.	.	.	1
	Othes species												
G rhiz	*Glyceria notata* Chevall.	.	.	.	1	1	+	.	.	2	1	1	6
H scap	*Lythrum junceum* Banks et Sol.	1	1	1	.	+	1	.	.	.	.	.	5
G rhiz	*Cyperus badius* Desf.	.	.	1	.	.	.	.	.	.	+	1	3
H scap	*Rumex conglomerates* Murray	.	.	.	+	.	.	.	.	1	.	.	2
H caesp	*Juncus effusus* L.	.	.	.	.	+	1	.	.	.	.	.	2
G Rhiz	*Juncus articulatus* L.	.	.	.	.	.	1	.	.	.	1	.	2
H rept	*Trifolium repens* L.	1	.	.	.	.	.	.	.	.	.	.	1
H scap	*Rumex pulcher* L.	.	1	.	.	.	.	.	.	.	.	.	1
H bienn	*Jacobaea erratica* (Bertol.) Fourr.	.	.	.	.	.	.	.	.	+	.	.	1
I rad	*Veronica anagallis-aquatica* With.	.	.	.	.	.	.	.	.	.	+	.	1
H caesp	*Juncus inflexus* L.	.	.	.	.	.	.	.	.	.	.	1	1

L. subsp. *amporitana* Sennen, and *Stellaria alsine* Grimm. Both these associations, therefore, appear quite different from the Sicilian assemblages. In Western Sicily, the assemblages dominated by *R. omiophyllus* host several differential species belonging the class *Isoëto-Nanojuncetea* (see Brullo and Minissale 1998) leading us to propose the institution of a new association, the *Junco bufonii-Ranunculetum omiophylli*. Its typical composition is made of species from both the *Callitricho-Ranunculetalia* and the *Isoëto-Nanojuncetea* classes.

Short description – Slightly sciophilous, batrachid community with a clear dominance of *R. omiophyllus*, frequently associated with annual micro-helophytes of the *Isoëto-Nanojuncetea* class such as *Juncus bufonius* L. and *Poa infirma* Kunth. The coenosis develops on muddy bottoms of shallow depressions (up to 10–20 cm) on clayey substrates. Its typical water bodies are small and have prolonged flooding phases, that last until the beginning of the summer season (June-July), and are also subjected to intense trampling disturb. The growth optimum of this new association is in late spring.

Bioclimate in Sicily – Mediterranean pluviseasonal-oceanic (meso-Mediterranean subhumid/humid).

Syndynamism – This association is in contact with several aquatic rooted coenoses (*Potamogetonetea* class) and in particular with *Callitriche stagnalis* communities, while it spread into the communities of the *Isoëto-Nanojuncetea* and *Molinio-Arrhenatheretea* Tüxen 1937 classes along the littorals of colonized wet depressions.

Local distribution – Frequent in small ponds located in the central-northern sector of the Bosco Ficuzza, within the municipalities of Godrano, Marineo, Mezzojuso, and Monreale.

Table 15. Synoptic table of the identified associations and communities belonging to class Lemnetea minoris in Western Sicily: 1) *Lemnetum minoris* von Soó 1927; 2) *Lemnetum gibbae* Miyawaki et J. Tüxen 1960; 3) *Lemna minuta* community; 4) *Potamogetono-Ceratophylletum submersi* Pop 1962.

Association number	1	2	3	4
Table number	1	2	3	4
Number of Relevés	7	11	4	4
Char. of association and upper units of the cl. *Lemnetea*				
Lemna minor L.	100	18	.	100
Lemna gibba L.	.	100	.	100
Lemna minuta Kunth	.	.	100	.
Ceratophyllum submersum L.	.	.	.	100
Trasgr. species of cl. *Potamogetonetea*				
Callitriche obtusangula Le Gall	71	18	.	100
Ranunculus rionii Lagger	14	.	.	25
Ranunculus aquatilis L.	.	36	.	100
Potamogeton trichoides Cham. et Schltdl.	.	9	.	.
Other species				
Glyceria notata Chevall.	100	.	.	25
Mentha aquatica L.	57	.	.	.
Chara sp.	29	.	.	.
Ranunculus ophioglossifolius Vill.	29	.	.	.
Equisetum telmateia Ehrh.	14	.	.	.
Alopecurus aequalis Sobol.	.	36	.	75
Bolboschoenus maritimus (L.) Palla	.	9	.	.
Mentha pulegium L.	.	9	.	.
Paspalum distichum L.	.	.	75	.

Conclusions

New insights on the aquatic communities of the *Lemnetea* (Table 15) and *Potamogetonetea* (Table 16) classes, characterized by the predominance of threatened and rare macrophytes, have been offered for western Sicily. The study puts in evidence the presence of a rich diversified aquatic and wet vegetation, namely four free-floating communities (ascribed to two different alliances, *Lemnion minoris* and *Stratiotion* – Tables 1–4), and 11 rooted plant assemblages (belonging to four alliances, *Potamogetonion*, *Nymphaeion albae*, *Ranunculion aquatilis*, and *Ranunculion omiophyllo-hederacei* – Tables 5–14).

This relative high vegetation diversity is probably mainly to be attributed to the wide ecological range of small-standing water ecosystems investigated, that includes both natural and artificial ecosystems, as well as permanent and temporary ponds, reservoirs, situated in turn on a variety of geo-lithological substrates (limestones, quartzarenites, clays, gypsum of the evaporitic series of the Sicilian interior) and altitudes, from the few meters a.s.l. of the mouth of the Carboj River (AG) to the 1,326 m a.s.l. of the Gorgo di Pietra Giordano (PA) (see Suppl. material 1, Table S1). Indeed, origin and hydroperiod of small water ecosistems are pivotal features in driving the complexity of vegetation in wetlands and small water bodies, especially in semi-natural or artificial contexts (Bolpagni and Piotti 2016; Bolpagni 2020).

Among the communities recognized, six are new for the study area (*Potamogetono-Ceratophylletum submersi*, *Potamogetonetum pusilli*, *Ranunculetum rionii*, *R. aquatilis*, *R. peltati*, and *Lemno-Callitrichetum obtusangulae*), and two have been described as new sintaxa: *Junco bufonii-Ranunculetum omiophylli* and *Ranunculetum peltati* subass. *ranunculetosum rionii*. The first is a batrachid community differentiated by annual micro-helophytes (*Juncus bufonius* and *Poa infirma*); whereas the second one is another batrachid assemblage differentiated by *Ranunculus peltatus* and *R. rionii*, well adapted to strong seasonal water level variations.

The present data greatly broaden the floristic-phytosociological knowledge of the aquatic communities of the largest Mediterranean island, as well as their syntaxonomic, synecological, and distributive features. Our survey allowed almost punctual evaluation of scattered, isolated aquatic habitats that have a relevant conservation value considering the huge pressures exerted by climate change and human activities in the Mediterranean region (Gianguzzi et al. 2013, 2017; Benavent-González et al. 2014; Angiolini et al. 2017; Tomaselli et al. 2020). Thus, the described vegetation includes very peculiar phytocoenoses, although the floristic originality of the aquatic communities monitored is generally low. Despite this, due to their rarity and to the fragmented distribution, vegetation dom-

Table 16. Synoptic table (semplificated) of the identified associations and communities belonging to class *Potamogetonetea pectinati* in Western Sicily, with companion taxa with less than 20% constancy reported at the end: 5) *Potamogetonetum natantis* Hild 1959; 6) *Potamogetonetum pusilli* von Soó 1927; 7) *Potamogetonetum pectinati* Carstensen ex Hilbig 1959; 8) *Groenlandietum densae* Segal ex Schipper et al. in Schaminée et al. 1995; 9) *Ranunculetum rionii* Hejný et Husák in Dykyjová et Květ 1978; 10) *Ranunculetum aquatilis* Géhu 1961; 11a) *Ranunculetum peltati* subass. *typicum* Horst, Krausch & Müller-Stoll 1966 em. Weber-Oldecop 1969; 11b) *Ranunculetum peltati* subass. *ranunculetosum rionii* subass. nov.; 12) *Lemno-Callitrichetum obtusangulae* (Philippi 1978) Passarge 1992; 13) *Callitriche stagnalis* community; 14) *Junco bufonii-Ranunculetum omiophylli* ass. nov.

Association number	5	6	7	8	9	10	11a	11b	12	13	14
Supplementary table number	5	6	7	8	9	10	11a	11b	12	13	14
Number of Relevés	20	7	8	4	25	14	7	7	17	5	11
Char. of association, subass. and upper units of the class *Potamogetonetea*											
Potamogeton natans L.	100	14	13	.	12	7	14	.	12	.	.
Potamogeton pusillus L.	10	100	.	.	4	21	.	.	.	.	.
Potamogeton pectinatus L.	.	.	100	.	12	7	.	.	.	.	.
Groenlandia densa (L.) Fourr.	.	.	.	100	.	.	.	.			
Ranunculus rionii Lagger	25	.	13	.	100	29	.	100	12	.	.
Ranunculus aquatilis L.	5	86	25	.	4	100	.	.	6	20	9
Ranunculus peltatus Schrank	10	.	.	.	.	.	100	100	.	.	.
Callitriche obtusangula Le Gall	5	.	.	50	8	14	.	.	100	.	18
Callitriche stagnalis Scop.	.	.	.	.	.	36	.	.	.	100	45
Ranunculus omiophyllus Ten.	.	.	.	.	.	.	.	.	6	80	100
Other species of the cl. *Potamogetonetea*											
Potamogeton trichoides Cham. et Schltdl.	5	.	25	.	.	.	14	14	.	.	.
Callitriche brutia Petagna	5	29	.	.	.	14	14	.	.	.	.
Trasg. of the cl. *Isoëto-Nanojuncetea*											
Mentha pulegium L.	.	.	.	.	32	29	14	28	29	20	36
Juncus bufonius L.	.	.	.	.	.	.	.	.	.	.	81
Poa infirma Kunth	.	.	.	.	.	.	.	.	.	.	64
Isolepis cernua (Vahl.) Roem. et Schult.	.	.	.	.	.	.	.	.	.	.	9
Trifolium micranthum Viv.	.	.	.	.	.	.	.	.	.	.	9
Ranunculus muricatus L.	.	.	.	.	.	.	.	.	12	.	9
Ranunculus angulatus C. Presl	.	.	.	.	.	.	.	.	.	.	9
Other species											
Glyceria notata Chevall.	15	86	13	100	56	86	100	100	59	100	55
Eleocharis palustris (L.) Roem. et Schult.	.	57	.	.	16	29	57	43	6	.	.
Juncus articulatus L.	.	29	.	50	24	14	.	.	.	.	18
Chara sp.	.	29	38	50	20	.	.	.	.	.	.
Typha angustifolia L.	10	.	25	.	12	.	.	.	.	.	.
Lemna minor L.	5	.	.	.	.	14	.	.	36	.	.
Phragmites australis (Cav.) Trin. ex Steud.	5	.	25	.	.	.	.	.	.	.	.
Mentha aquatica L.	.	.	.	25	20	.	.	14	36	.	.
Lythrum junceum Banks et Sol.	.	.	.	25	.	.	.	.	6	20	45
Alisma lanceolatum With.	.	.	.	.	28	14	.	57	6	.	.
Oenanthe fistulosa L.	.	.	.	.	4	.	14	86	.	.	.
Juncus effusus L.	.	.	.	.	8	.	.	.	.	.	18
Alopecurus aequalis Sobol.	.	.	.	.	.	21	.	.	6	20	.
Ranunculus ophioglossifolius Vill.	.	.	.	.	.	7	.	.	25	20	.
Rumex pulcher L.	.	.	.	.	.	7	.	.	6	.	9
Rumex conglomeratus Murray	.	.	.	.	.	7	.	.	12	.	18
Ceratophyllum submersum L.	.	.	.	.	.	14	.	.	12	.	.
Jacobaea erratica (Bertol.) Fourr.	.	.	.	.	.	7	.	.	.	.	9
Lemna gibba L.	.	.	.	.	.	.	43	.	.	20	.
Veronica anagallis-aquatica L.	.	.	.	.	.	.	.	14	.	20	9
Myosotis sicula Guss.	.	.	.	.	.	.	29	.	.	.	.
Cyperus badius Desf.	.	.	.	.	.	.	.	.	.	.	27

Taxa with less than 20% constancy and presence in singular table: Tab. 6) *Cladophora* sp. 13%; Tab. 8) *Coronopus squamatus* 8%, *Bolboschoenus maritimus* 8%, *Persicaria amphibia* 4%, *Paspalum distichum* 4%, *Rumex crispus* 4%, *Ranunculus angulatus* 4%; Tab. 11a) *Galium debile* 14%; Tab. 13) *Oenanthe aquatica* 20%; Tab. 14) *Juncus inflexus* 9%, *Trifolium repens* 9%.

inated by lemnids or species of the genera *Potamogeton* or *Ranunculus* (sect. *Batrachium*) can be listed among the most endangered plant communities at national and European scale (Bolpagni et al. 2017; Maiorca et al. 2020). However, the study also highlights some critical issues including the presence of the invasive species *Lemna minuta*. We confirm its strongly invasive character, as shown elsewhere in Italy, especially in eutrophic environments (Ceschin et al. 2016; Lastrucci et al. 2016 and references therein).

To sum up, the present work offers a preliminary overview of the spatial representativeness of macrophyte communities in a rich set of small wetlands and ponds in western Sicily. Despite their very small size, which makes them very sensitive environments, they represent a fundamental component of semi-natural and natural ecosystems, which require adequate protection and monitoring actions in Sicily, and more generally in the Mediterranean region and in the world.

Syntaxonomical scheme

LEMNETEA MINORIS O. de Bolòs et Masclans 1955
LEMNETALIA MINORIS O. de Bolòs et Masclans 1955
Lemnion minoris O. de Bolòs et Masclans 1955
Lemnetum minoris von Soó 1927
Lemnetum gibbae Miyawaki et J. Tüxen 1960
Lemna minuta community
Stratiotion Den Hartog et Segal 1964
Potamogetono-Ceratophylletum submersi Pop 1962

POTAMOGETONETEA PECTINATI Klika in Klika et Novák 1941
POTAMOGETONETALIA Koch 1926
Nymphaeion albae Oberdorfer 1957
Potamogetonetum natantis Hild 1959
Potamogetonion Libbert 1931
Potamogetonetum pusilli von Soó 1927
Potamogetonetum pectinati Carstensen ex Hilbig 1971
Groenlandietum densae Segal ex Schipper et al. in Schaminée et al. 1995
CALLITRICHO HAMULATAE-RANUNCULETALIA AQUATILIS Passarge ex Theurillat in Theurillat et al. 2015
Ranunculion aquatilis Passarge ex Theurillat in Theurillat et al. 2015
Ranunculetum rionii Hejný et Husák in Dykyjová et Květ 1978
Ranunculetum aquatilis Géhu 1961
Ranunculetum peltati Horst, Krausch & Müller-Stoll 1966 em. Weber-Oldecop 1969
typicum
ranunculetosum rionii subass. nov.
Lemno-Callitrichetum obtusangulae (Philippi 1978) Passarge 1992
Callitriche stagnalis community
Ranunculion omiophyllo-hederacei Rivas-Martínez et al. 2002
Junco bufonii-Ranunculetum omiophylli ass. nov.

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Appendix - Localities and date of relevés

Table 1 - Rels 1-2: C.da Sovarita (Marineo) 03.06.2013; rels 3-4: Margiazzo del Vallone Arcere (Monreale) 02.06.2019; rel. 5: contrada Cannitello (Godrano) 23.04.2019; rel. 6: Portella di Granza (Sclafani Bagni) 25.05.2019; rel. 7: Lago Bomes (Sclafani Bagni) 25.05.2019.

Table 2 - Rel. 1: Torrente Mandrarossa (Menfi) 08.08.2019; rels 2-3: Monte Cofano (Custonaci) [Tab. 3 in Gianguzzi & La Mantia (2008)]; rels 4-5: Case Cuttitta (Godrano) 16.05.2013; rel. 6: Lago Soprano (Serradifalco) [pag. 16 in Marcenò & Raimondo (1977)]; rel. 7: Monte Palmeto (Cinisi) 15.05.2019; rels 8-9: Gorgo Lungo (Godrano) 28.08.2020; rels 10-11: Gorgo Cerro (Monreale) 01.06.2018.

Table 3 - rels 1-2: Gorgo S. Rosalia (Palermo) 02.05.2010; rel. 3: Cozzo Grattarola (Palermo) 10.03.2019; rel. 4: Gorghi Tondi (Mazara del Vallo) 06.05.2019.

Table 4 - rels 1-2: Gorgo Lungo (Godrano) 16.05.2013; rels 3-4: Gorgo Lungo (Godrano) 01.06.2018.

Table 5 - rel. 1: c.da Cucco (Godrano) 11.06.2014; rel. 2: Bosco Granza (Sclafani B.) 25.05.2019; rel. 3: Gorgo Pollicino (Petralia Sop.) 01.07.2019; rel. 4: Monte Carcaci (Castronovo S.) 03.06.2019; rel. 5: Case Scalilli (Corleone) 05.06.2014; rel. 6: Gole del Drago (Corleone) 05.06.2014; rel. 7: Gole del Drago (Corleone) 05.06.2014; rel. 8: Valle Maria (Godrano) 12.05.2014; rel. 9: Case Renzi (Monreale) 14.05.2013; rel. 10: Paraturazzu (Mezzojuso) 12.05.2014; rel. 11: Pietra Giordano (Geraci S.) 01.07.2019; rel. 12: Bosco Granza (Sclafani B.) 25.05.2019; rels 13-14: Piano Guddemi (Godrano) 07.05.2013; rel. 15: laghetto "ru zù Rusulinu" (Godrano) 20.05.2013; rel. 16: c.da Bifarera alta (Monreale) 14.05.2013; rel. 17: c.da Bifarera alta (Monreale) 14.05.2013; rel. 18: c.da Bifarera alta (Monreale) 14.05.2013; rels 19-20: c.da Coda di Riccio (Godrano) 25.05.2013.

Table 6 - rel. 1: Case Javuti (Casteldaccia) 24.05.2019; rels 2 and 6: Laghetto "ru zù Rusulinu" (Godrano) 01.06.2018; rels 3-4: Gorgo Pizzo Selva a Mare (Trabia) 24.05.2019; rels 5 and 7: Cozzo Valdaro (Trabia) 24.05.2019.

Table 7 - rel. 1: Lago Soprano (Serradifalco) [pag. 17 in Marcenò & Raimondo (1977)]; rel. 2: c.da Alpe Cucco (Godrano) 11.06.2014; rel. 3: c.da Casale (Corleone) 05.06.2014; rel. 4: c.da Cicio (Corleone) 05.06.2014; rel. 5: Gorgo S. Andrea (Castronovo S.) 03.06.2019; rel. 6: Foce Fiume Carboj (Menfi) 25.07.2019; rel. 7: c.da Casale (Corleone) 05.06.2014; rel. 8: c.da Nicolosi (Corleone) 05.06.2014.

Table 8 - rels 1-2: Bosco Granza (Sclafani B.) 25.05.2019; rels 3-4: Monte Carcaci (Castronovo S.) 29.05.2013.

Table 9 - rel. 1: Gorgo Carcaci (Castronovo S.) 02.06.2018; rel. 2: Piano Garufi (Mazara del Vallo) 13.04.2019; rel. 3: Piano Guddemi (Godrano) 17.05.2013; rel. 4: Chiano Prani (Godrano) 20.05.2013; rel. 5: c.da Alpe Cucco (Godrano) 11.06.2014; rels 6-7: c.da Coda di Riccio (Godrano) 24.05.2012; rel. 8: c.da Coda di Riccio (Godrano)

25.05.2012; rels 9-10: Valle Maria (Godrano) 12.05.2014; rel. 11: c.da Casale Soprano (Monreale) 12.06.2013; rel. 12: c.da Casale (Monreale) 05.06.2014; rels 13-14: c.da Bifarera (Monreale) 14.05.2013; rel. 15: Portella di Piro (Godrano) 16.05.2013; rel. 16: Pizzo Nicolosi (Monreale) 14.05.2013; rel. 17: Case del Duca (Godrano) 12.06.2013; rel. 18: c.da Monticchio sottano (Godrano) 24.04.2014; rel. 19: c.da Largo di Bosco (Monreale) 27.04.2014; rels 20-21: c.da Bifarera alta (Monreale) 14.05.2013; rels 22-23: Gorgo Rebuttone (Altofonte) 04.07.2015; rel. 24: c.da Biviere (Godrano) 16.05.2013; rel. 25: Monte Palmeto (Carini) 13.04.2019.

Table 10 rel. 1: c.da Monticchio soprano (Godrano) 03.06.2013; rel. 2: c.da Cannitello (Godrano) 03.06.2013; rel. 3: c.da Casale (Monreale) 12.05.2014; rel. 4: Laghetto "ru zù rusulinu" (Godrano) 20.05.2013; rel. 5: Gorgo di Rebuttone (Altofonte) 04.07.2015; rels 6-7: Gorgo Pizzo Selva a Mare (Trabia) 24.05.2019; rels 8-9: Gorgo Glaviano (Godrano) 24.04.2014; rel. 10: c.da Sovarita alta (Marineo) 03.06.2013; rel. 11: Gorgo Cerro (Monreale) 09.05.2013; rel. 12: Valle Maria (Godrano) 20.05.2013; rels 13-14: Gorgo Lungo (Godrano) 16.05.2013.

Table 11 - rel. 1: Gorgo dei Palermitani (Monreale) 09.05.2013; rels 2-3: Monte Cofano (Custonaci) 05.05.2018; rels 4-5: Pantani di Anguillara (Calatafimi) 05.05.2018; rel. 6: Monte Carcaci (Castronovo S.) 02.06.2018; rels 7-8: Piano Guddemi (Godrano) 17.05.2013; rels 9-10: Gorgo Quattro Tummini (Godrano) 17.05.2013; rels 11-12: Gorgo Carcaci (Castronovo S.) 02.06.2018; rels 13-14: Marosa (Godrano) 17.05.2013.

Table 12 - rel. 1: Fosso Pietra Giordano (Geraci S.) 01.07.2019; rel. 2: Gurgo Pietra Giordano (Geraci S.) 01.07.2019; rel. 3: Sovarita (Marineo) 20.05.2013; rel. 4: Bosco Granza (Sclafani B.) 25.05.2019; rel. 5: c.da Coda di Riccio (Godrano) 25.05.2013; rels 6-7: Case Franco (Godrano) 20.05.2013; rel. 8: c.da Monticchio sottano (Godrano) 24.04.2014; rel. 9: c.da Zotta Frascino (Monreale) 07.05.2013; rel. 10: Pizzo Campana (Godrano) 10.05.2013; rels 11-12: Margiazzo Vallone Arcere (Monreale) 09.05.2013; rel. 13: Cozzo Bileo (Marineo) 06.06.2013; rel. 14: Portella di Granza (Sclafani B.) 25.05.2019; rel. 15: Lago Bomes (Sclafani B.) 25.05.2019; rels 16-17: Gorgo Lungo (Godrano) 16.05.2013.

Table 13 - rel. 1: Pizzo Angelo (Mezzojuso) 21.05.2014; rel. 2: c.da Valle Fono (Godrano) 10.05.2013; rel. 3: c.da Acqua Jenco (Mezzojuso) 21.05.2014; rel. 4: Sorgente Acqua Accetta (Marineo) 07.05.2013; rel. 5: Gorgo Cerro (Monreale) 09.05.2013.

Table 14 - rel. 1: Piano Carduna (Monreale) 09.05.2013; rel. 2: Piano Carduna (Monreale) 09.05.2013; rel. 3: c.da Acqua Jenco (Mezzojuso) 21.05.2014; rel. 4: c.da Sovarita alta (Marineo) 03.06.2013; rel. 5: Cozzo Bileo (Marineo) 06.06.2013; rel. 6: c.da Acqua Jenco (Mezzojuso) 21.05.2014; rel. 7: Sorgente Acqua Accetta (Marineo) 07.05.2013; rel. 8: Valle Fono (Godrano) 10.05.2013; rel. 9: c.da Sovarita alta (Godrano) 03.06.2013; rel. 10: Pizzo Angelo (Mezzojuso) 21.05.2014; rel. 11: c.da Acqua Jenco (Mezzojuso) 21.05.2014.

Supplementary material 1

Table S1

Authors: Orazio Caldarella, Lorenzo Lastrucci, Rossano Bolpagni, Lorenzo Gianguzzi

Data type: geographical data

Explanation note: Location and physical features of the freshwater habitats investigated.

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Supplementary material 2

Figures S1-S3

Authors: Orazio Caldarella, Lorenzo Lastrucci, Rossano Bolpagni, Lorenzo Gianguzzi

Data type: images

Explanation note: Images of the study area and vegetation.

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